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TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, October, 1921 No. 1

A SUCCESSFUL CONCLUSION TO A SUCCESSFUL YEAR

WITH the Third Annual Convention and Exhibition of the American Society for Steel Treating passed, another achievement has been accomplished. In spite of the fact that the country is beclouded with an industrial depression which demands a policy of economy, both the Convention and Exhibition were distinct successes. It was a fitting finish for the first year of the new society. Just one year ago the Society was newly organized by the amalgamation of two smaller heat treating societies. It was then a great task to knit the two memberships into one working unit and to determine the policies which would guide the activity of the organization in the future.

These problems were soon solved. Reports of national officers proved this. Within one year's time the membership enjoyed a growth of 18 per cent or 487 members, raising the total from 2750 to 3237 on Sept. 1, 1921. Local chapters have increased from 27 to 31 and a new one is to be installed shortly at Rockford, Ill. Several more applications have been received. It is most unfortunate that the entire membership was not present at Indianapolis to hear the report of the National Treasurer. With all bills paid the treasury contained a substantial cash reserve, indicating that the Society is approaching a position for increased service as a result of its financial position. Possibly research in steel treating lines is not far distant.

Considerable interest was shown in the technical sessions of the Convention where many valuable papers were presented. Some 80 papers were presented, about half of this number being presented by title. It is to be regretted, however, that a lack of time prevented proper discussion being given each paper, for the great purpose of all technical conventions is to discuss pertinent problems of the trade. Lack of time for discussion had been anticipated and brief abstracts of the papers were distributed to assist in provoking discussion, but the abstracts proved to be so brief that they were of little use in this respect. It will prove advantageous in the future to either limit the number of papers presented, or to extend the time for their discussion. This matter must receive careful attention before the next Convention.

Retiring officers of the Society must be commended for their work during the past year for it has been by their efforts that the organization is able to take its place among the leading technical societies of the country. And it is with the best wishes and assurance of co-operation that the membership greets the new officers.

FRANK P. GILLIGAN
Elected National President of the American Society for Steel Treating

Officers of The American Society for Steel Treating

1921–22

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A. E. WHITE
Director, Department of Engineering Research, University of Michigan,
Ann Arbor, Mich.

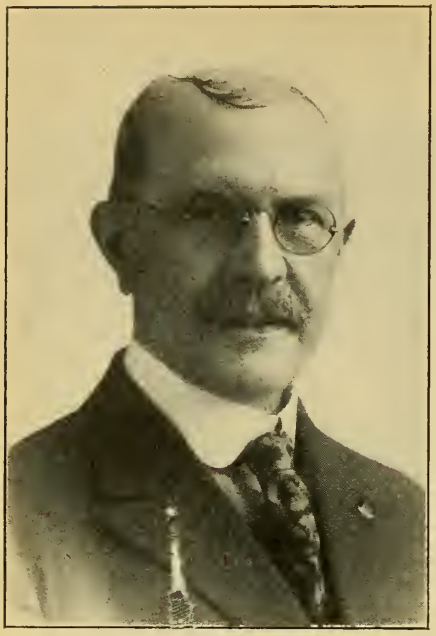
INDIANAPOLIS CONVENTION SETS NEW RECORD IN ATTENDANCE AND NUMBER OF PAPERS PRESENTED

WITH 1475 registered members and guests in attendance at the Third Annual Convention at Indianapolis, Sept. 19-24, a new high record was set for attendance. This showing seems remarkable in view of the fact that the Society has but 3237 members. Unusual interest was attached to the meetings which were well attended. In all some 80 papers were presented, about half by actual presentation and the remainder by title. Unfortunately, however, the number of papers presented was too great for the time allowed, thus what little discussion was permitted was not productive of much result. A necessary postponement of the Wednesday afternoon session also assisted this congestion.

Several new features were introduced in the program this year and included the use of simultaneous sessions and the introduction of research and management and costs into the subjects for consideration. Without doubt both of these will receive more attention in the future. Much credit must be given to the Indianapolis Chapter which arranged the entertainment program for their guests, for no detail had been overlooked. The entertainment features were a highlight of the Convention.

Opening Session on Monday

The Third Annual Convention of the American Society for Steel Treating was opened Monday afternoon, Sept. 19, in the Manufacturers' building, Indiana State Fair grounds, Indianapolis. W. R. Chaplin chairman of the executive committee of the Indianapolis Chapter welcomed the Society to the city on behalf of the local chapter. Claude Wallin, secretary to Mayor Jewett welcomed the Society to Indianapolis and his greeting was responded to by Lieut. Col. A. E. White, National President, who then assumed the chair.



F. C. LAU
Elected First Vice President of the Society

R. J. ALLEN
Elected Second Vice President of the Society

J. V. EMMONS
Elected National Treasurer of the Society

J. J. CROWE
Elected National Director of the Society

The regular order of business was conducted as scheduled. R. T. Bayless, chairman of the tellers of election reported that 606 ballots were cast for the new officers, however, 14 ballots were defective and were thrown out, leaving an actual count of 592 ballots for the new officers, whose names and photographs appear on other pages of this issue.

W. S. Bidle, National Treasurer, read his report which briefly rehearsed the financial affairs of the Society from the time of amalgamation of the two societies at Philadelphia last year to Sept. 1, 1921. At the latter date, every obligation had been met and a substantial cash balance was deposited in the treasury. The satisfactory showing was made possible by the greatest of co-operation between the national officers and directors in directing the affairs of the Society. W. H. Eisenman, National Secretary, in his annual report outlined the growth and activities of the Society during the past year. He announced that at the time of amalgamation the organization had 2750 members, which number has since increased to 3237, an increase of 487 or 18 per cent. Likewise local chapters have increased from 27 one year ago to 31 at the present time, chapters having been granted to Syracuse, Charleston, Gary and Worcester. He also announced the granting of a chapter to Rockford, Ill., the installation to take place in the near future. The Secretary's address appears in full on page 25 of this issue. The afternoon session was brought to a close with the annual address of the President in which Lt. Col. White summarized in detail the activities of the Society and made a number of recommendations for the guiding of affairs in the future. President White's address appears on page 16.

Program of Technical Sessions

With some slight changes in the program, the technical meetings were conducted as scheduled. Carburizing was the subject of the technical meeting held on Tuesday morning, J. Culver Hartzell, consulting metallurgist, Blue Ash, O., being chairman. The papers presented at this meeting were: "A Comparison of the Rate of Penetration of Carbon Into Various Commercial Steels in Use for Case Carbonizing," by S. C. Spaulding, metallurgist, Halcomb Steel Co., Syracuse, N. Y.; "Do Alloy Carbonizing Boxes Pay?" by C. M. Campbell, superintendent, Pioneer Alloy Products Co., Cleveland; "Carbonizing with Wood Charcoal," by H. Schagrin, chief chemist, United States naval ordnance plant, Charleston, W. Va.; and "The Design of Heat Treating Containers," by H. H. Harris, president, General Alloy Co., Chicago.

Simultaneous sessions were held on Tuesday afternoon, one session being devoted to tool steel with F. B. Foley presiding, and the other devoted to the heat treatment of special products with H. M. Boylston, professor of metallurgy, Case School of Applied Science, Cleveland, as chairman. Papers presented at the tool steel session were: "Physical Tests on High Speed Steel," by A. H. D'Arcambal, metallurgist, Pratt & Whitney Co., Hartford, Conn.; "Influence of the Heating Medium on Structural Changes in Steel," by A. E. Bellis, president Bellis Heat Treating Co., New Haven, Conn.; "Preparing Tool Steel at the Mill," by A. W. F. Green, metallurgist, John Illingworth Steel Co., Philadelphia; and "Tool Steel Manipulation," by L. K. Marshall, metallurgist, North East Electric Co., Rochester, N. Y.

At the special products session, consideration was given to the following papers: "Dow Metal and Its Application," by J. A. Gann, research department, Dow Chemical Co., Midland, Mich.; "Brass Forgings," by H. L.

Hess, H. L. Hess Co., Philadelphia; "Duralumin," by W. B. Stout, president Stout Engineering Laboratories, Detroit; and "Heat Treatment of Copper and Brass," by F. L. Helrigel, metallurgist, Motor Products Co., Detroit.

Because of the postponement of the 50-mile automobile race from Wednesday morning to Wednesday on account of rain, the technical program for the afternoon was postponed until Thursday when the papers were read at an extra session during the afternoon. Simultaneous meetings were held Thursday morning, one session with Dr. J. Culver Hartzell presiding being called the army and navy session and the other with C. N. Dawe, metallurgical engineer, Studebaker Corp., Detroit, as chairman, discussing alloy steel.

The program of the army and navy session was general in nature. Lieut. Charles Bradner, chief chemist, chemical warfare service, presented a paper on "Poisonous Gases," Commander George Leary, United States navy, presented two papers, "The North Sea Barrage" and "Railway Gun Mounts," both being illustrated. "Planning and Routing of Forging and Heat Treatment Work at Watertown Arsenal" was the subject discussed by F. C. Langenburg, metallurgist Watertown arsenal, Watertown, Mass.

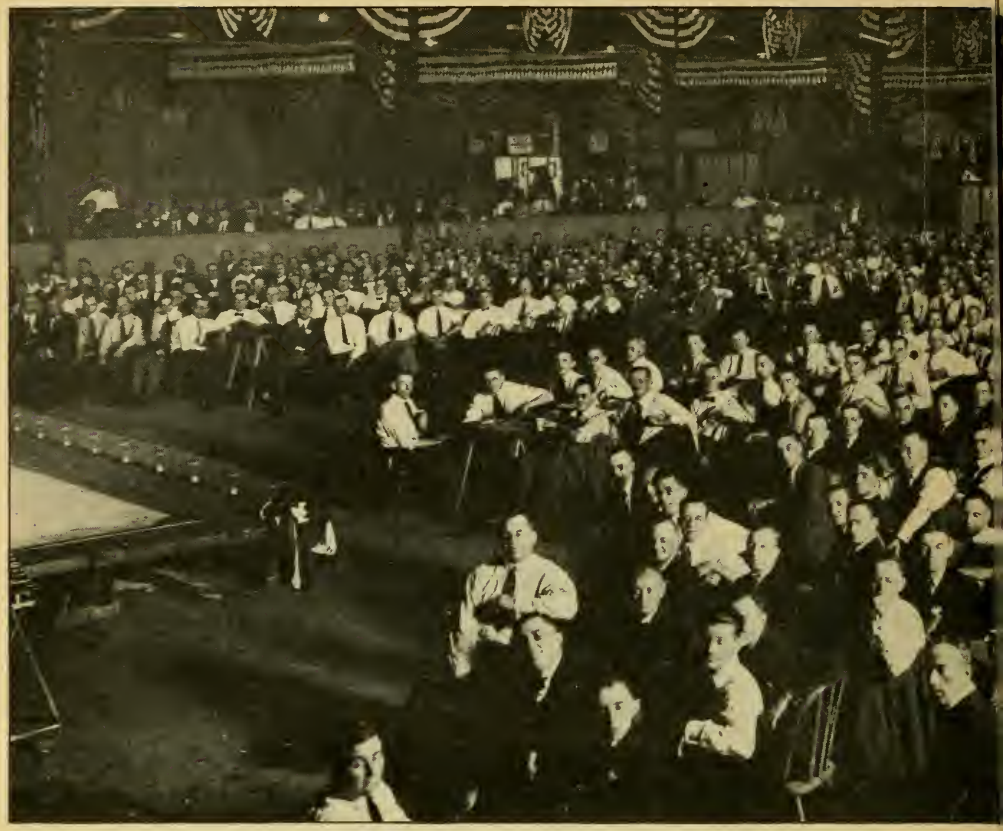
Papers discussed before the alloy steel group were: "Effect of Heat

THE OPENING SESSION OF THE CONVENTION WHICH WAS HELD

Treatment on the Mechanical Properties of a Carbon-Molybdenum and a Chrome-Molybdenum Steel" by H. J. French, physicist, bureau of standards, Washington; "A Comparison of American and English Methods of Producing High Grade Crucible Steels" by T. Holland Nelson, steel works manager, H. Disston & Sons, Philadelphia; "Mechanical Properties of Chrome Vanadium Steels" J. S. Vannick, metallurgist, fixed nitrogen research laboratory. Washington; and "Toughness of Alloy Steels as Affected by Their Heat Treatment" by M. H. Grossman, metallurgist, Electric Alloy Steel Co., Charleroi, Pa.

Three simultaneous sessions were conducted Thursday afternoon. The first on metallographic research with O. E. Harder, professor of metallurgy, school of mines, University of Minnesota, as chairman, considered the following papers: "Metallography of High Speed Steel" by J. P. Gill and L. D. Bowman, metallurgists, Vanadium Alloy Steel Co., Latrobe, Pa.; "Some Alloy Steels of High Elastic Limit; Their Microstructure and Heat Treatment" by C. M. Johnson, director of research, Crucible Steel Co. of America; "Efficiency of Different Mixtures for Cyanide Hardening and the Role of Nitrogen in the Process" by V. E. Hillman, metallurgist, Cromp-

IN THE MANUFACTURERS BUILDING ON MONDAY AFTERNOON



A PHOTOGRAPH OF THE SMOKER WHICH WAS HELD ON TUESDAY EVENING.

ton & Knowles Loom Works, Worcester, Mass.; "Ghost Lines and Grain Elongations in Hot Rolled and Cold Drawn Low Carbon Steel Wire" by N. B. Hoffman, metallurgist, Colonial Steel Co., Pittsburgh; and "Heat Treatment of Chrome Steel for Ball Bearings" by H. Styri, chief of S. K. F. Research Laboratories, Philadelphia.

The second session with A. W. F. Green, metallurgist, John Illingworth Steel Co., Philadelphia, presiding, discussed heat treating equipment, the papers presented being as follows: "Automatic Compensation for Variations of Cold Ends of Thermoelectric Pyrometers" by W. H. Bristol, president, the Bristol Co., Waterbury, Conn.; "Skipping the A. B. C's to Talk the X. Y. Z's of Temperature Measuring Instruments" by George Keller, sales manager, Brown Instrument Co., Philadelphia; and "A New Type Regulator; Its Application to Heat Treating Problems" by R. W. Newcomb, manager, Charles Engelhard, Inc., New York.

The third session also on heat treating equipment and with T. D. Lynch, metallurgical engineer, Westinghouse Electric & Mfg. Co., Pittsburgh, as chairman discussed the papers: "Construction of Furnace Doors, Linings and Bases" by E. F. Davis, sales engineer, Celite Products Co., New York; "An Electrically Heated Forging and Heat Treating Furnace" by G. M. Little, Westinghouse Electric & Mfg. Co., Pittsburgh; "What Insulation

WAS A WARM EVENING AS EVIDENCED BY THE DISCARDING OF COATS

Will Do for the Heat Treater" by T. J. Gower, sales engineer, Armstrong Cork & Insulation Co., Pittsburgh; "Gas Accessories for the Heat Treating Room," J. Weaver Smith, industrial engineer, Citizens Gas Co., Indianapolis; and "Operating Data on Electric Furnaces" by R. E. Talley, chief engineer, George J. Hagan Co., Pittsburgh.

Two meetings were held on Friday morning, one of which was the research session with H. E. Howe, chairman, division of research extension, national research council, as chairman. Papers presented were: "Field Industrial Research" by E. F. Hyde, director of research, Nela research laboratory, Cleveland; "National Aspect of Research" by C. A. Adams, chairman, division of engineering, national research council; "What the University Owes the Industries" by Prof. A. E. White, director of engineering research, University of Michigan, Ann Arbor, Mich.; "The Role of Government Laboratories in Industrial Research" prepared by George K. Burgess, chief of division of metallurgy bureau of standards, Washington.

Management and costs were considered at the other morning session presided over by Dr. Culver Hartzell, the papers presented being: "Determination of Heat Treating Costs" by H. F. Wood, chief metallurgist, Ingalls-Shepard Division, Wyman-Gordon Co., Harvey, Ill.; "Buying Steel

on Closer Carbon Limits" by E. W. Pierce, chief metallurgist, Maxwell Motor Co., New Castle, Ind.; "A Successful Bonus System Applied to Heat Treating" by A. A. Blue, metallurgist, Duff Mfg. Co., Pittsburgh; and "The Electric Furnace as It Affects Overall Costs of Heat Treated Parts" by C. L. Ipsen, designing engineer, General Electric Co., Schenectady, N. Y.

Heat treating problems were considered at the Friday afternoon session with H. J. French, physicist, bureau of standards, as chairman. The papers discussed were: "Coarse Grained Forgings, Their Detection and Correction" by L. S. Cope, metallurgical engineer, Dannemore Steels, Inc., New York; "Tests Showing the Effect of High Temperatures on Malleable Iron" by T. D. Lynch and W. J. Merten, metallurgical engineer, Westinghouse Electric & Mfg. Co., Pittsburgh; "Fracture Tests on Steel to Determine Its Quality" by W. J. Priestly, superintendent hot metal division, United States naval ordnance plant, Charleston, W. Va.; "A Contribution to the Problems of the Influence of Mass on Heat Treatment" by E. J. Janitzky, metallurgist, Illinois Steel Co., South Chicago, Ill.; and "A Coiling and Heat Treating Plant for Helical Springs" by W. J. Merten, metallurgical engineer, Westinghouse Electric & Mfg. Co., Pittsburgh.

Many more papers were presented by title at the various sessions, but these papers are not mentioned here since a complete list of all papers appeared in the September issue of TRANSACTIONS. Abstracts of the various papers appear on page 32 of this issue.

Two Honorary Members Elected

Meetings of chapter delegates together with the national officers were held on Tuesday and Thursday noons immediately following lunch. While

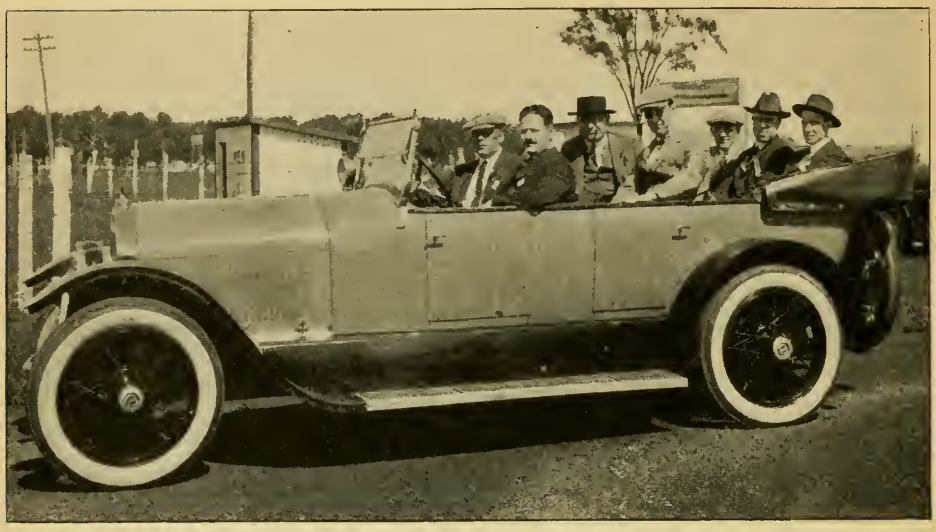
NEARLY 400 ATTENDED THE ANNUAL BANQUET ON THURSDAY EVENING AT TH

many questions were discussed, probably the most important matter considered was the co-operation between the officers and members of local chapters and between local chapters and the national organization. A meeting of the board of directors was held on Thursday and at that time elected to honorary membership in the Society Dr. John A. Mathews, president Crucible Steel Co. of America, Pittsburgh, and Elwood Haynes, president Haynes Motor Car Co., and Haynes Stellite Co., Kokomo, Ind. Both men are prominent in steel treating and metallurgical work, Doctor Mathews for his investigations with molybdenum steels and Mr. Haynes for his invention of a nonferrous cutting alloy. With the election of Doctor Mathews and Mr. Haynes, the number of honorary members of the society was increased from four to six.

Entertainment Provided Is a Feature

Special mention must be made of the entertainment program which was one of the features of the Convention. Due credit must be given the Indianapolis Chapter which through George Desautels, chairman of the entertainment committee, had provided a most complete and elaborate series of events for the entertainment of members and their guests. A smoker was held in the Manufacturers Building on Tuesday evening. Practically every available seat was taken and standing room was utilized, it being estimated that over 2000 attended. In spite of the fact that Mr. Desautels claimed the Indianapolis police station was well supplied with "Anti-Volstead Quenching Medium," a number of kegs of cider was the best the committee was able to provide, and the hardness number of that is a secret. Plenty of doughnuts were supplied as were cigars and cigarettes.

LAYPOOL HOTEL. THE SPEAKERS' TABLE IS SHOWN IN THE RIGHT CENTER



The pacemaker which started the 50-mile race. From left to right are: William Thompson, president Stutz Motor Car Co. of America, Indianapolis; W. H. Eisenman, national secretary of the society; Barney Oldfield, former race driver, Cleveland; Chester Ricker, director of timing, official of American Automobile association; Gil Anderson, sales manager, Duesenberg Automobile & Motors Co., Inc., Indianapolis, and former race driver; Lieut. Col. A. E. White, president of the society; and F. P. Gilligan, president-elect of the society

The function had been announced as a smoker and it was a smoker with the air thick and blue but the atmosphere was far from the same. With many songs and a first-class vaudeville and cabaret show going on continuously, it was a jolly good crowd. Colonel White received his share of the good time and permitted George Desautels to slip one over on him when he was presented with a brand new phonograph packing case. But when the Colonel took invoice of the contents he found it contained the next number on the program—a dancing maiden. The Colonel's acceptance was cut short by a hasty exit from the stage. A photograph of the smoker is shown on page 8 and had it been taken later in the evening instead of at the start could have been captioned "Ain't We Got Fun."

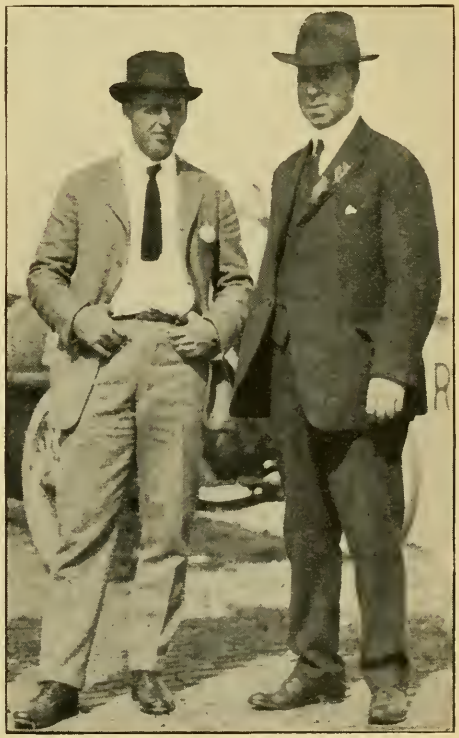
A 50-mile automobile race at the Indianapolis Motor Speedway on Wednesday morning perhaps was the biggest event on the program. The race was scheduled for 10 a. m. but a heavy rainfall in the early morning necessitated postponement until noon and also a reducing of the distance from 100 to 50 miles. Because of lack of time qualification tests were eliminated, the drivers drawing for position. The race, which was the first ever to be held on the Indianapolis course outside of the usual Memorial Day events, was sanctioned by the American Automobile Association, with the agreement that any records made would be official. Seven cars were entered, three Frontenac, three Duesenberg and one Peugeot. Details of the cars, drivers and speed are given as follows:

Order of Finish	Car	Driver	Time
First	Peugeot	Howard Wilcox	30:50.64
Second	Duesenberg	Jimmy Murphy	31:27.85
Third	Frontenac	Jules Ellingboe	32:23.18
Fourth	Duesenberg	Joe Thomas	32:25.48
Fifth	Duesenberg	Eddie Hearne	34:19.75
Sixth	Frontenac	Charles Van Ranst	36:27.22
	Frontenac	Bennie Hill	Car Wrecked

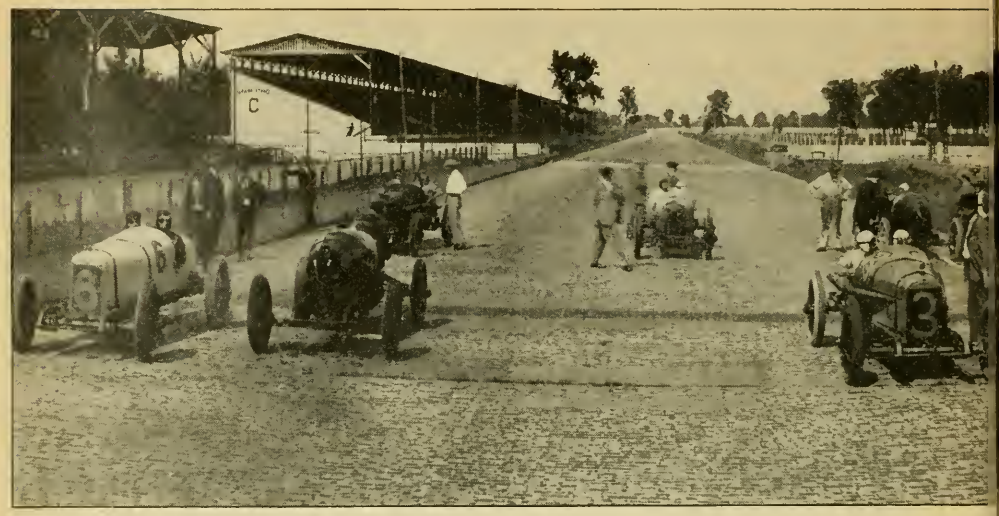
Howard Wilcox, driving a French Peugeot, won the race, averaging 97.5 miles per hour. Jimmy Murphy, recent winner of the Grand Prix, was second in a Duesenberg, losing the lead which he commanded from the very start until the last lap when engine trouble developed and he was forced to limp across the finish line. An unfortunate incident of the race was the wrecking of Bennie Hill's Frontenac car in the tenth lap and while holding third place. Both the driver and his mechanician, Henri Frank, miraculously escaped serious injury and death when their car jumped the retaining wall on the south turn and flew high into the air landing about 100 feet from the point at which it went over the wall. Hill received cuts about the head and face and a number of body bruises, and Frank was scratched and bruised. Both were taken to the hospital where their condition was reported as not serious.

Hill was rounding the south turn at a speed estimated at about 85 miles an hour when his car suddenly veered and disappeared from sight. An ambulance was rushed from the infield, but because the car had jumped the wall, it was not located for several minutes. The racer was a complete wreck. According to persons who witnessed the mishap, the car, after going over the wall, was hurled through the air, breaking a telephone pole and landing with the drivers pinned beneath it. The accident was described as being one of the most spectacular ever witnessed at the speedway.

The lineup of the various cars as they appeared before the race



(Left) Lieutenant-Colonel White congratulates Jimmy Murphy upon second place in the 50-mile automobile race. (Right) Tommy Milton, prominent automobile race driver, and Lieutenant-Colonel White



The seven racing cars lined up for the start of the 50-mile race at the Indianapolis Motor Speedway. Fr
Puegeot driven by Howard Wilcox; Duesenberg No. 3 driven by Eddie Hearn; Duesenberg No. 16 driv
Ranst. The pacemaking car is shown at the extreme right. The race was won by Howard Wilc
Bennie Hill was wrecked when

started is shown above. Approximately 10,000 people were in the grandstands and represented the members of the Society and their invited guests. Just before the 50-mile race started two Fronty-Fords, equipped with special racing heads made by the Chevrolet Bros. Mfg. Co., Indianapolis, provided a 10-mile match race. An exhibition trial lap of the Duesenberg champion of the world was also run. This car averaged 156.4 miles per hour at Daytona, Fla. Following the big race two airplanes gave an exhibition of stunt flying, however, strong air currents prevented an extensive demonstration.

Annual Banquet Held on Thursday Evening

On Wednesday evening the Indianapolis Chapter entertained with an informal dance in the ballroom of the Claypool Hotel. Many members and guests attended. The Third Annual Banquet of the Society was held in the Riley Room of the Claypool Hotel on Thursday evening with about 400 members, ladies and guests attending. Following the serving of the banquet, Lieut. Col. White presided, calling upon Governor Warren T. McCray of Indiana and Mayor Charles W. Jewett of Indianapolis for short addresses. At the request of Secretary W. H. Eisenman, a standing vote of appreciation was tendered the retiring president following which Dr. Albert Sauveur, honorary member of the Society assumed the chair as toastmaster. The first address was given by A. A. Potter, dean of engineering, Purdue University, Lafayette, Ind. Dean Potter was a representative of the American Society of Mechanical Engineers and spoke briefly of the progress made by that society, pointing out how the American Society for Steel Treating could accomplish similar results. The second address, "The Spirit of Research in Engineering and Industry" was given by Prof. Comfort A. Adams, director of the engineering division of the National Research Council.

The principal address of the evening was, "Our Air Policies and the

t to right are shown Duesenberg No. 6 driven by Jimmy Murphy; Frontenac No. 9 driven by Bennie Hill; Joe Thomas; Frontenac No. 1 driven by Jules Ellingboe; and Frontenac No. 2 driven by Charles Van o averaged 97.5 miles per hour. Jimmy Murphy was second and Jules Ellingboe third. The car of nt over the wall in the tenth lap

National Defense," by Howard E. Coffin, vice president of the Hudson Motor Car Co., and member of the Naval Advisory Board. Mr. Coffin give a very eloquent talk and received a close following from his audience. He stressed the importance that airplanes would play in future armament policies of the world, and illustrated his convictions by many lantern slides and two reels of moving pictures of the recent airplane bombing tests conducted at Sandy Hook. The speaker also pointed out industrial unpreparedness handicapped the United States in its entry into the war. As a remedy for this in the future Mr. Coffin advocated the placing during peacetime of provisional contracts by the government. In event of war telegraphic notice would be sufficient to start production.

Presented Tokens of Appreciation

A number of excellent and unusual vaudeville features were dovetailed into the banquet program, which lasted until after 1 a. m. Near the close of the banquet Mr. Desautels as chairman of the Entertainment Committee was presented with a handsome gold watch and chain and Mrs. Desautels as chairman of the Ladies Entertainment Committee was presented with a beautiful diamond broach, the gifts signifying the appreciation for the splendid entertainment provided during the week.

The entertainment for the ladies as arranged by Mrs. Desautels included a visit to the exhibition on Monday evening, a theater party on Tuesday evening, a style show at one of the big department stores, several luncheons and automobile rides to various points of interest in Indianapolis.

Throughout the week members of the Society had the opportunity of visiting industrial plants in the city. The inspection trips were headed by various members of the Indianapolis Chapter. A list of the plants open for visitation was given in the September issue of TRANSACTIONS.

ANNUAL ADDRESS OF THE PRESIDENT

By A. E. White

Lieut.-Col. A. E. White

TO THE Directors, Delegates and Members of the American Society for Steel Treating:

I take pleasure in presenting for your consideration a statement of the work of the American Society for Steel Treating during the fiscal year 1920-21. I further take the liberty of incorporating in this report various recommendations and suggestions relative to the conductance of the work of the Society during the coming years, to which it is trusted that your national and local officers will give due consideration.

With much gratification do I acknowledge the splendid support which I have received as your President from your national officers, the support which they have received from the local chapter officers, and the support which they, in turn, have received from the membership at large. We must realize that no matter how conscientious and efficient officers you may have, they can accomplish little unless they have the whole-hearted and enthusiastic support of the membership as a whole. Such support has been the case this past year and I feel confident in predicting that the same will be true throughout the succeeding years.

I hesitate to commend anyone of your officers more than another for all have taken their work in the fullness of the trust that has been placed upon them and have given of their time, energy and thought unstintingly. Yet, I must speak of the excellent work which has been done by our National Secretary and by our National Treasurer.

Our Secretary, W. H. Eisenman, has been at his desk both days and nights, has thought of the Society at all hours, has been ever tactful, ever full of visions for its further development and progress and has been of great moment in bringing the Society to its present high standard of efficiency and service. Our National Treasurer has been a bulwark of strength in the activities of our Society. He has given the equivalent of days and weeks of his time without compensation. He was of great service in assisting our National Secretary at the time of the establishment of the offices in Cleveland and he placed his own offices at the service of our Society until such time as it was possible for us to move into our national headquarters. The sane, constructive financial policies which our Treasurer has enunciated these last 12 months will live for years to come and I believe we can with all due honor point to W. S. Bidle as the Alexander Hamilton of our Society.

Membership

The year 1920-21 has been a most successful one for this Society. The combined membership at the time of the amalgamation of the American Steel Treaters' Society and the Steel Treating Research Society was

approximately 2750. On Sept. 1, 1921, the membership of the American Society for Steel Treating was 3237. This represents a growth of 487 members during the past 12 months' period or an increase of substantially 18 per cent. Appreciating the unusual conditions which have existed during this period, growth of this magnitude is both surprising and gratifying.

Our chapters, also, have increased in number from 27 to 31; the new chapters taken in being our Syracuse, Charleston, Worcester and Gary chapters. The directors also have acted favorably upon the request from Rockford, Ill., for the establishment of a chapter and three other industrial centers have broached requests for chapters.

Finances

Our financial status is sound with a sufficient balance on hand today to carry us over any untoward periods, should such develop. I will not name any figures in this report as these will be given by our National Treasurer but as I have examined his monthly statements the substantial increases in free balance are an indication of the strong support which the Society is receiving from its members and the efficient method of handling and operating the Society.

Honorary Members

There have been elected to Honorary Membership this past year two metallurgists of national prominence and note. One is Prof. Albert Sauveur of Harvard University and the other is Prof. E. D. Campbell of the University of Michigan. Both men have rendered our civilization a distinct service in their findings and researches in the constitution and properties of iron and steel. In addition to these two men we have as honorary members Dr. Henry Marion Howe and Sir Robert Hadfield.

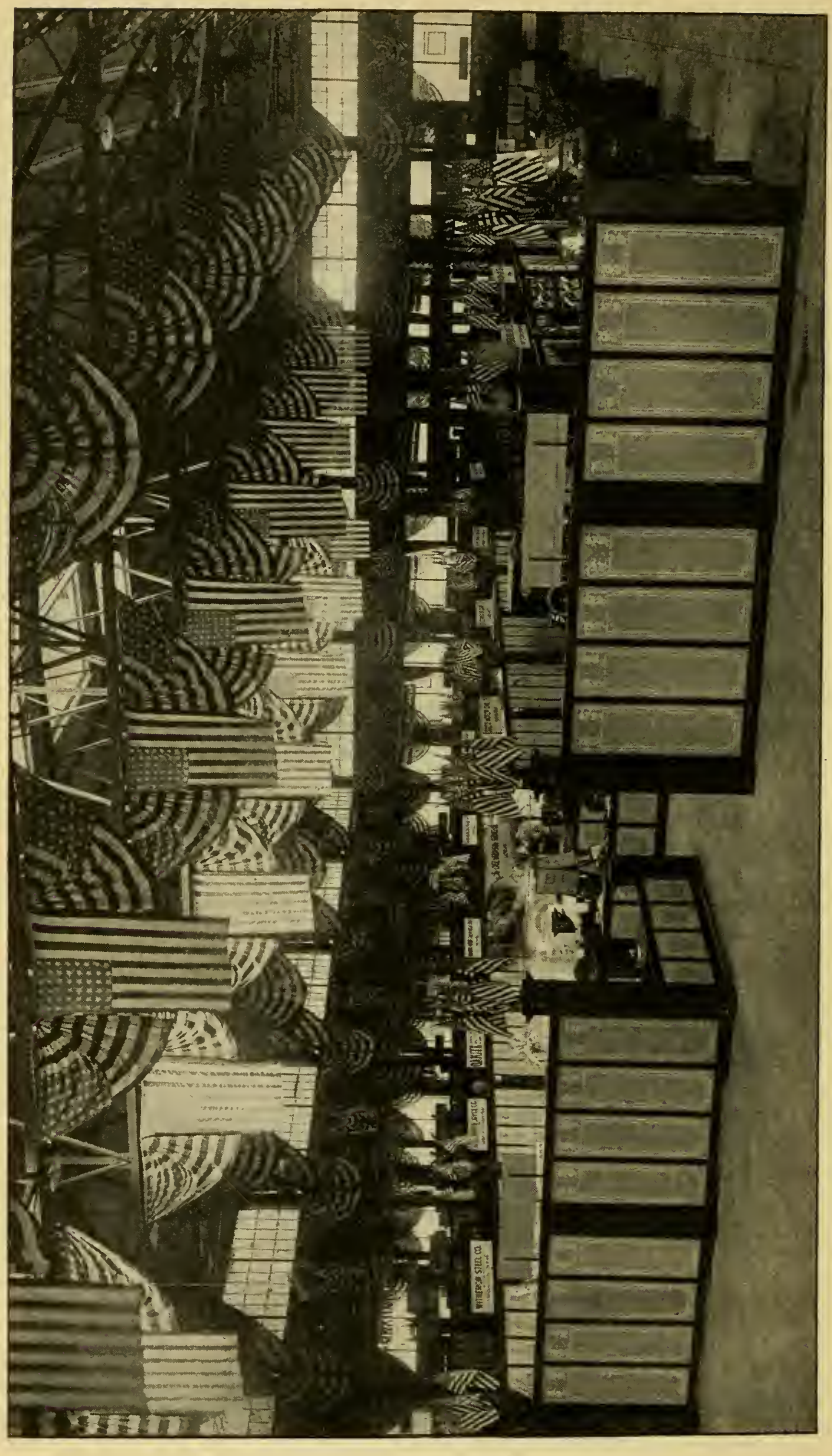
National Committees

The By-Laws of the Society call for nine national committees. By the authority of the Constitution and By-Laws vested in the President, I have appointed a further national committee which I have designated as the Program Committee, the membership of which consists of Harold Brown, Tri-City Chapter, Chairman, Dr. J. Culver Hartzell, Cincinnati Chapter and Don H. Stacks, Hartford Chapter. All of these 10 committees have organized and are beginning to give much consideration to their respective problems. In national societies the development of committee work is naturally a slow process but we may all feel gratified at the progress that has been made.

Our Finance Committee has been engaged in the control and supervision of our financial policies. These have been sound as evidenced by the excellence of the report which our Treasurer will make.

Our Publication Committee under the able direction of Prof. H. M. Boylston has given much thought and time to the general nature and character of our TRANSACTIONS. I have yet to hear from a single individual that our TRANSACTIONS as they stand before you today are not decidedly superior to what they were a year ago; both in the careful editing of the various manuscripts printed and in the general makeup and style of the magazine. Due credit in this connection should be accorded to our editor, E. F. Ross.

Our Meetings and Papers Committee has assumed the responsibility for the preparation of the program for the Convention. It was with regret that the resignation of Howard J. Stagg, Chairman of this Com-



A GENERAL VIEW OF THE INDIANAPOLIS EXHIBITION LOOKING TOWARD THE ENTRANCE

mittee was accepted. Prof. H. L. Campbell was appointed as his successor and the technical papers which will be given at this Convention were procured under his direction. George O. Desautels as a further member of this Committee has assumed all responsibility for the entertainment during the Convention.

Our Library Committee has been giving much thought to making possible the procurement of technical data desired by our membership. Dr. J. Culver Hartzell, Chairman of this Committee, has been particularly enthusiastic in this matter and has presented a report outlining a procedure which it is believed is so practicable that with the Directors' concurrence it will be put into effect this coming year.

Our Standards Committee has been attempting to ascertain how it can best operate without infringing upon or duplicating the work now so ably performed by our American Society for Testing Materials, our American Society of Mechanical Engineers, and our Society for Automotive Engineers. The annual report of the Chairman of this Committee, T. D. Lynch, gives indication that they are finding themselves and that they will be able to render the Society a distinct service without duplicating work now already done by other societies.

Our Research Committee have also been attempting to find themselves and to prepare recommendations relative to future activities. The situation is not one, essentially, of finding work but rather one of finding funds with which to do work. It is a dream of your President, though he has not as yet broached this matter to the Directors, that the time will come when our Convention and Exhibition will net the Society a sufficient sum so that our Research Committee may have funds available with which to work. Though our Society is today on a strong financial footing it is not yet in a position to support work of this type however much it may desire to do so; though it is trusted that in the not far distant future funds may be available from within the Society proper or through the donations of private individuals.

Our Constitution and By-Laws Committee with Capt. C. D. McQuigg as Chairman have given very serious consideration to the question of whether or not certain of the articles in our Constitution and By-Laws are for the best interests of the Society. It is their opinion that admission to the membership class should be broadened somewhat. They have also recommended certain other minor changes. All of these have been favorably acted upon by the Directors and within the next few weeks will be transmitted to the voting membership for confirmation.

The Nominating Committee met in session in the Spring of 1921 and prepared the slate which you elected to office this summer.

Our Membership Committee was extremely active during the fall, winter and spring of 1920-21. Much credit for our increase in membership must be laid to the activities of this Committee which was so ably directed by our First Vice President, T. E. Barker and upon his moving from Chicago to Denver by J. Fletcher Harper.

Our Program Committee which has only been appointed within the past few months places itself at the service of the various chapters for the purpose of recommending to them, when desired, possible speakers and subjects for chapter meetings. It is not the thought or intention of this Committee to make such recommendations unless the same are requested because we desire our chapters in all cases to feel free to con-

duct their activities and work in such manner as they see fit, provided only that they comply with the Constitution and By-Laws of the Society to which they have already subscribed.

Transactions

Casually our TRANSACTIONS has been mentioned in the work of the Publication Committee. We are all to be congratulated, I feel, in belonging to an organization which has such an excellent magazine. The articles presented are well written, well edited and set forth the most recent and up-to-date developments which are daily taking place in the field of heat treatment. We are most pleased in the excellent improvement in the character of our magazine during the past year. I do not know that there are any who could bring about the improvement as rapidly or more consistently than has been done by our editor and by our Publication Committee.

Yet, it is the prerogative of the President at this one time to incorporate in his report such suggestions as he believes may be for the good of the Society. In this connection I would be-speak an arrangement of this magazine so that it may cover more adequately, even more than it does today, the field of heat treatment. It is my personal feeling that in its pages we should cater to the technical man and to the shop man. Our articles, though not necessarily in the same contribution, should be of interest to both classes and they should be so arranged that there will be no misunderstanding relative to the purposes for which the articles are prepared. The technical man should be able to find without difficulty the articles he desires to read, and the shop man should be able to find without difficulty the articles which he is particularly interested in looking over. In this same connection we should give greater attention to our abstracts and trade notes.

The former would be of particular interest to the technical man and the latter to the shop man.

Thus I believe that our reading matter should very definitely be divided into four groups: (1) technical, (2) shop notes, (3) abstracts, (4) trade notes. To the first we have already given much consideration and doubtless most of the articles presented would be assigned to this group. The second is at present a fallow field. It is one which, if cultivated, will grow and develop and become of much interest and service to our shop man. The third field, abstracts, is one which has already been suggested by a number of those interested in the Society. It will go far, it is believed, in rendering that service to the membership of the Society which has been so admirably recommended by the Chairman of our Library Committee, Dr. J. Culver Hartzell. It will mean that not only will our membership have available the many technical articles which now appear in our own TRANSACTIONS; but also it will render possible a comprehensive survey of all activities in the field of heat treatment as now recorded in the technical press of the day. An excellent start has been made in the trade notes under "Commercial Items of Interest". These brief statements are personally of much interest to me and I feel that they must be of equal interest to the membership as a whole.

Two further fields which the publication covers are the "News of the Chapters" and the "Employment Service Bureau". The information contained in the "News of the Chapters" gives one a perspective with regard to the activities of neighboring chapters and cannot fail to stir our

local chapter executive committees with desires for emulation. It further renders valuable aid and assistance to our executive committees by giving them indirect suggestions relative to the proper method of handling and arranging their local chapter programs and activities.

Chapter Meetings

Your National Officers fully appreciate that the strength of the Society is fundamentally and unequivocably tied up with the strength of the respective chapters. They have not attempted to dictate in any manner relative to the chapter programs, feeling that each chapter knew its own local conditions best, although they have been much concerned with regard to them and with regard to the general procedure leading up to their development. With 31 chapters in as many different centers, there are of necessity those manifesting great strength and those giving evidence of some weakness. It has been my privilege to visit 26 of the 31 chapters and because of this privilege I take this opportunity of presenting for your consideration certain observations which have been forcefully brought to my attention.

Selection of Executive Committee

I believe it is of paramount importance that great care and thought be employed in the selection of your Executive Committees. Pick out for this work men who have the reputation for taking their responsibilities seriously and who can be depended upon to follow through any program until they see the same successfully completed. If you appoint for your Executive Committee men of that caliber and type I believe you need have no fear for the success of your chapter during the year in which they are in office. I can give instances of promises made and broken and I can give instances in greater number, I assure you, of promises made and kept. Those who have made promises and failed made them in my judgment with the best of intentions and with every desire to carry them to a successful fruition. Yet, their failure has been due in quite a large measure to a lack of a proper follow up system, because human nature is so ordered that most of us need to be repeatedly reminded of the things we have agreed to do in order that we may carry them through.

Alliance With Other Engineering Societies

There is an old saying "In union there is strength". This seems to be the case with our technical societies for I have noted that where our chapters are in close alliance with other technical societies in their own communities there is always a successful chapter. Further, I have noted that our weaker chapters are, for the most part, those which exist in communities where there is no bond of union between the technical societies. In view of this condition, therefore, I strongly recommend to the various chapters in this Society that they make every possible effort to co-operate with the various technical societies in their community and unite with them by alliance when such is possible, for in no case have I yet found that such alliance involves lack of identification with the national societies to which each group belongs. I believe our Directors look with favor upon uniting with the Federated American Engineering Societies but have not joined this federation at present because of the cost entailed, which as we now stand would involve an expenditure of something like $4800. This matter is brought up at this

BOOTHS WERE ATTRACTIVELY AND NEATLY ARRANGED AS SHOWN IN THIS ILLUSTRATION

time to indicate that the failure of your National Society to join the Federated American Engineering Societies is due to financial considerations rather than to lack of sympathy with the movement.

Character of Meetings

I submit for your consideration three suggestions relative to the character and nature of your meetings. These matters are being given due consideration by the Program Committee but the suggestions contained are ones which I have culled from my book of experience during this past year.

(a) *Nature of Program*—Fundamentally I believe that our local program committees should make every possible effort to provide at each session a proper combination of the technical and that which, for lack of a better term, I will call the entertaining. There is an old saying that "All work and no play makes Jack a dull boy and all play and no work makes Jack a big shirk". I believe our technical societies as a whole have operated without due appreciation of the significance of the truth of this proverb. I believe the reason why it has been so difficult to procure proper attendance at many of the sessions of our technical societies has been due to the lack of anything of an entertaining character on our programs. In the entertaining we do not need to go to the vulgar either as set forth in so many of our moving pictures today or in the activities of many of our cabaret entertainers. Yet, we do need that which will bring a smile and a laugh as well as we need that which will lead toward the development of our technical knowledge. Our churches for long years have seen this need, for in addition to the sermon we have congregational singing and selections from well-trained choirs or quartettes with well-modulated voices. Personally I cannot understand why our technical societies have been so backward in appreciating this proper demand for the technical and the entertaining. I hope that during this year our chapters will take care of this feature to a greater extent even than they have done in the past through the incorporation into their program, in addition to the technical, of such drawing cards as refreshments, smokers, moving pictures, speakers known for their ability to produce a laugh and such cabaret features as are worth while.

(b) *Date and Place for Meeting.* It has been my observation that those chapters which meet at a given time each month and which have a definite meeting place are always assured of good attendance. I know the claim is made that speakers of note cannot be procured on any given date. Personally I feel such claims are made only by those who, in the preparation of their program, have delayed in its arrangement to the last minute and have been compelled, therefore, to adopt their date to the engagements of the speaker rather than for the speaker to adopt his program to the arrangements of the Chapter. Personally I feel that every chapter should have a most definite date for meeting and that a strong effort should be made to have the meeting place always in the same building. The practice of sending out notices to the members two or three days preceding the date of the meeting results in poor attendance and in much absence.

(c) *Program.* It is recommended that each local chapter arrange during the summer the program for the fall, winter and spring meetings. This committee should very properly arrange its program with no

thought of the speakers and on the arrangement of the program then they should make every effort to get the speaker desired for the program projected. Whether the talent be from within the chapter or outside is a matter for each local chapter to settle. There is a difference of opinion on this matter and I have observed that chapter interest is procured in both ways.

Conclusion

I wish to express my personal appreciation for the co-operation and assistance rendered me by every member, by every local officer, by our national standing committees and by the eight other members of your Board of Directors, whom I have learned to love and admire through the contact which it has been my privilege to have with them. I bespeak the same co-operation for your new officers who are about to assume the reins of responsibility and trust. Though in but a few days I will step down as President of your Society you can can rest assured that it will always have my heartfelt interest and that you can depend upon me for any possible service which lies within my power to render.

REPORT OF THE NATIONAL SECRETARY

By W. H. Eisenman

THE National Headquarters of the American Society for Steel Treating were established in Cleveland on Dec. 1, 1920. Work with the Philadelphia Convention and the necessary details involved in preparation for the change together with the fact that the offices rented were not available until the 15th of January delayed the process of moving until the date mentioned. The change necessitated the establishing of an entirely new office force and many changes in the method of keeping records were instituted. At the time of the amalgamation, the Society had 27 local chapters; since that time four new chapters have been organized, those of Syracuse, N. Y., Charleston, W. Va., Gary, Ind., and Worcester, Mass., while a charter has been granted by the Board of Directors for the establishing of a chapter in the city of Rockford, Ill. Practically all chapters have reported excellent attendance at their monthly meetings during the past winter, and all of them have made extensive plans and preparations for the coming year. The average attendance all of the chapters have had at their meetings has been approximately 100 members and guests, which means that there are 3000 individuals attending meetings of the Society each month, with a total attendance of over 30,000 for the year.

One of the most pleasing evidences of the worthiness of your Society is the fact that during the past year of industrial depression, the Society has shown a growth of 18 per cent in membership. On Sept. 15, 1920, the membership was 2750; on Sept. 1, 1921, the membership numbered 3237, an increase of 487.

The free employment service has functioned this year with considerable success, and as business conditions open up, should be able to be of much greater service to its members and the manufacturing industries.

Your National Secretary during the past year has traveled over 35,000 miles in looking after the interests of the Society. He has visited practically all of the chapters, and has been present at their regular meetings.

One of the most important developments the Society has made during the past year has been the increased value of its publication, TRANSACTIONS. The general makeup and appearance have been improved decidedly under the efficient editorship of E. F. Ross, while the number of pages has been increased. Over 780 pages of reading matter, exclusive of advertising, have been published in the 12 numbers since last September.

Special commendation should be given to the Publication Committee consisting of Messrs. Boylston, Emmons, and Thum for the painstaking efforts and large amount of time they have given in reading the papers submitted for publication. Special credit should be given to the firms using the pages of TRANSACTIONS as an advertising medium. Through all the vicissitudes of business, they have remained loyal and continuous for all of which the members of the Society are truly grateful and appreciative. The prospects for the future are especially bright and encouraging.

During the past year, the Society has not only increased its field of usefulness by extending its service to new members, but has also in-

creased its financial condition. The Society has not yet made an impression upon the field of possible members or of its potential usefulness, but the plans for the future now being formulated slowly with great thought and care, led on in the future as in the past by a spirit of usefulness and service, will continue to direct the Society to even more successful achievements.

MANY COMPANIES DISPLAY PRODUCTS AND EQUIPMENT AT INDIANAPOLIS EXHIBITION

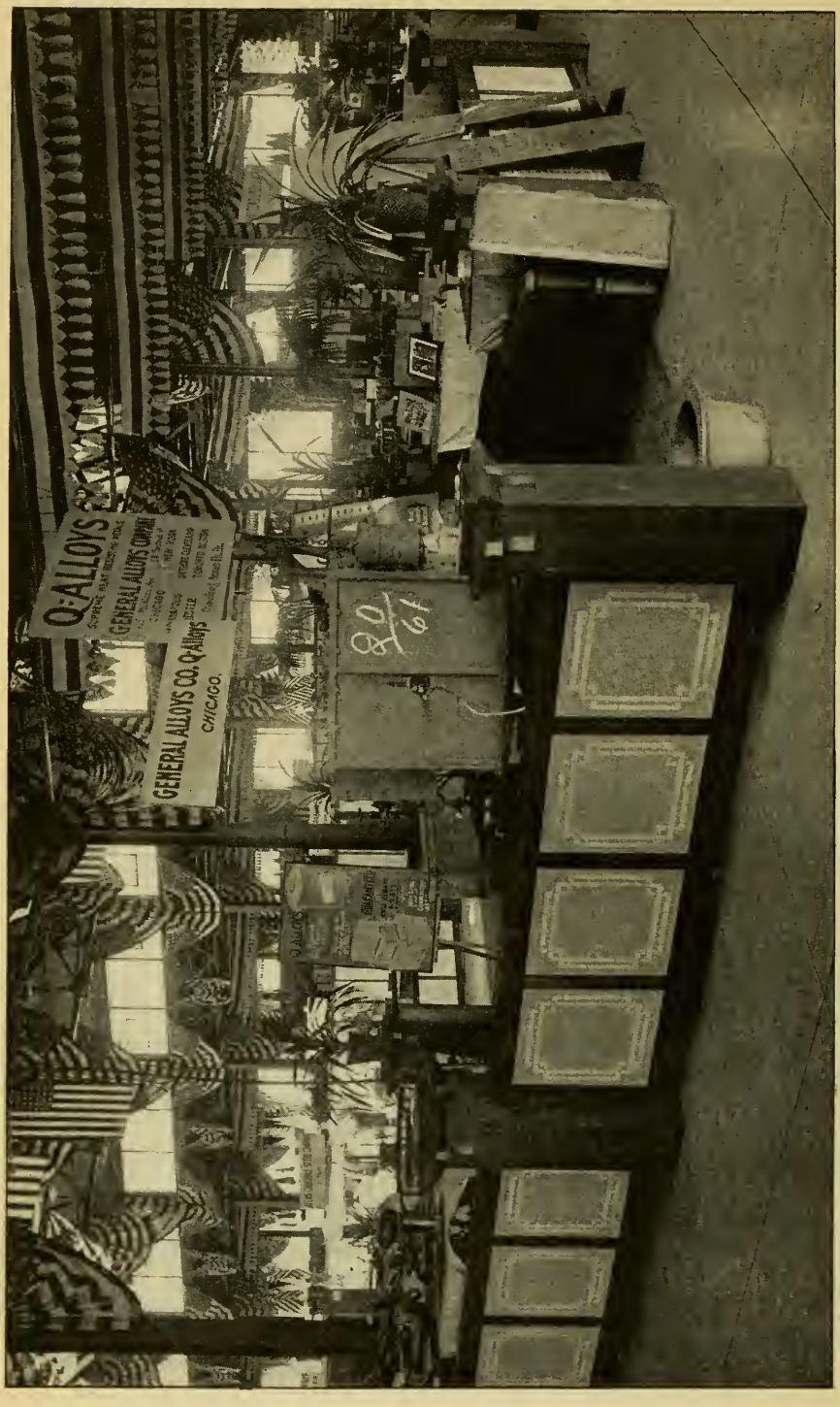
ABOUT seventy manufacturers of steel treating equipment and heat treated products were represented with booths and displays at the exhibition held in the Manufacturers building. The hall was attractively decorated and the booths were well arranged, showing up effectively. Many of the exhibits, particularly those of furnaces, machinery and recording devices, were shown in actual operation, gas, compressed air and electricity being provided. Exhibition views are shown on accompanying pages.

During the six days the convention was open, approximately 10,000 people attended. In addition to being open throughout the day, the exhibition was open on Monday and Friday evenings. Saturday was known as Indiana Day, when the displays were thrown open to the public.

Following is the complete list of exhibitors represented by booths at Indianapolis. A list of equipment which they showed was given in September issue of TRANSACTIONS.

Alcorn, Blockhouse Co., Philadelphia, Pa.
Armstrong Cork & Insulation Co., Pittsburgh, Pa.
E. C. Atkins Mfg. Co., Indianapolis, Ind.
Bausch & Lomb Optical Co., Rochester, N. Y.
Bell & Gossett Co., Chicago, Ill.
Bethlehem Steel Co., Bethlehem, Pa.
Bristol Co., Waterbury, Conn.
Brown Instrument Co., Philadelphia, Pa.
Bureau of Standards, Washington, D. C.
Calorizing Co. of America, Pittsburgh, Pa.
Case Hardening Service Co., Cleveland, O.
Celite Products Co., New York.
Central Steel Co., Massillon, O.

LOOKING DOWN ONE OF THE AISLES IN THE EXHIBITION HALL



ANOTHER TYPICAL VIEW TAKEN IN THE MANUFACTURERS BUILDING

Chevrolet Bros. Mfg. Co., Indianapolis, Ind.
Cole Motor Car Co., Indianapolis, Ind.
Colonial Steel Co., Pittsburgh, Pa.
Crucible Steel Co. of America, Pittsburgh, Pa.
Deeds Commercial Laboratories, Indianapolis, Ind.
Deeds & Chapin Co., Indianapolis, Ind.
Domhoff & Joyce, Cincinnati, O.
Driver-Harris Co., Harrison, N. J.
Electric Alloy Steel Co., Youngstown, O.
Forging & Heat Treating, Pittsburg, Pa.
Electrical Refractories Co., East Palestine, O.
Charles Englehard, Inc., New York.
J. B. Ford Co., Wyandotte, Mich.
William Ganschow Co., Chicago, Ill.
General Alloys Co., Chicago, Ill.
General Electric Co., Schenectady, N. Y.
George J. Hagan Co., Pittsburgh, Pa.
Haynes Motor Vehicle Car Co., Kokomo, Ind.
Halcomb Steel Co., Syracuse, N. Y.
Heppenstall Forge & Knife Co., Pittsburgh, Pa.
Hoskins Mfg. Co., Detroit, Mich.
Imperial Drop Forging Co., Indianapolis, Ind.
Indianapolis Drop Forging Co., Indianapolis, Ind.
The Iron Age, New York.
The Iron Trade Review, Cleveland, O.
Kinney Mfg. Co., Chicago, Ill.
Lafayette Motor Car Co., Indianapolis, Ind.
Leeds Northrup Co., Philadelphia, Pa. ,
Lexington Motor Car Co., Connersville, Ind.
Machinery, New York.
Marschke Mfg. Co., Indianapolis, Ind.
Maxon Furnace & Engineering Co., Muncie, Ind.
Midvale Steel & Ordnance Co., Cambria Steel Co., Pittsburgh, Pa.
National Motor Vehicles Corp., Indianapolis, Ind.
National Refining Co., Indianapolis, Ind.
Oakley Chemical Co., New York.
Quigley Furnace Specialties Co., Inc., New York.
W. S. Rockwell Co., New York.
P. H. & F. M. Roots Co., Connersville, Ind.
Shore Instrument & Mfg. Co., New York.
Simonds Mfg. Co., Lockport, N. Y.
Smith Gas Engineering Co., Dayton, O.
Spencer Turbine Co., Hartford, Conn.
Stevenson Gear Co., Indianapolis, Ind.
Stromberg Electric Co., Chicago, Ill.
Stutz Motor Car Co., Indianapolis, Ind.
Surface Combustion Co., New York.
Tate-Jones & Co., Inc., Pittsburgh, Pa.
Taylor Instrument Co's., Rochester, N. Y.
Vanadium-Alloys Steel Co., Latrobe, Pa.
Vonnegut Hardware Co., Indianapolis, Ind.
Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
Wilson-Maeulen Co., New York.
Witherow Steel Co., Pittsburgh, Pa.

WHAT THE TRADE JOURNALS SAY

BOTH *The Iron Trade Review* and the *Iron Age* in the Sept. 29 issues of their publications, carried editorials regarding the recent convention of the Society. They should be of interest to readers of TRANSACTIONS and need no comment. *The Iron Trade Review* editorial reads as follows:

Steel Treaters Make Progress

"Accomplishments of the American Society for Steel Treating, which held its annual convention in Indianapolis last week, may be accorded notable recognition in the progress of American engineering societies. Although but one year old and formed by the amalgamation of two smaller societies devoted to the same purpose, the new organization has enjoyed a steady and well-rounded growth. When the United States entered the war, and the requirement of vast quantities of ordnance and special material became imperative, the knowledge of the science of heat treatment was comparatively limited. Considerable information began to be accumulated as production got under way and it was indicated that an important technical field had been neglected. Thus was felt the need for one great society to guide and inspire the collection of information and to promote research in a science which bears so heavily on the production of steel products.

"As a result of this influence the American Society for Steel Treating was formed by joining together the two smaller societies which had organized shortly before. At the time of amalgamation the total membership was 2750. During the past year this has been increased to 3237, a growth of 18 per cent. Local chapters now number 31 as compared with 27 one year ago. Permanent national headquarters have been established and the monthly publication has been made larger and more representative of the field it covers. The organization is in a sound financial condition. All this progress achieved during the past year has been made in the face of unfavorable business conditions. Thus, without doubt greater advancement can be expected with the return of a more normal situation. The society may well take pride in the record it has made."

The *Iron Age* editorial reads as follows:

Progress In Heat Treatment

"If the number of technical and other papers presented at last week's annual convention of the American Society for Steel Treating be the criterion, then progress in heat treatment has been marked in the past year. Over 70 papers were prepared dealing with carbonizing, tool steel, alloy and high speed steel, heat treating problems and equipment, metallographic research and various other subjects. Many of the papers were of a high order and registered a marked advance in the practical and theoretical knowledge of the art. For an

organization only three years old, such an accomplishment is a credit to the enthusiasm of the members and the efficiency of the officials. Few of the older societies could do as well.

"If, however, our measure of the progress in heat treatment be the amount of information actually made public and discussed at the convention last week, the results would not be so pronounced. Without doubt one of the principal benefits of such a convention to those who take the trouble to attend is the hearing and discussion of the largest number of papers possible. The preprinting of a few papers and this followed by a full discussion is productive of the largest measure of profit, in contrast with the presentation by title or verbal abstract of a large number of topics and almost no discussion. The latter was the situation last week. With no papers preprinted and with many of the printed abstracts inadequate, there resulted a distinct disappointment in the lack of opportunity to discuss some of the topics. Another unfortunate phase of such a procedure is that since all the papers are held for publication in the society's monthly journal, many of the important papers cannot be made public until late in the year, and this is naturally a damper on the enthusiasm of some authors.

"There has been marked progress in heat treatment. The co-operation of some of the country's best metallurgists last week and the genuine enthusiasm and interested attendance at the sessions, particularly at those on alloy and other steels, is proof positive of progress in the knowledge of the subject and of a desire for mastery of it by the rank and file."

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ABSTRACTS OF PAPERS PRESENTED AT INDIANAPOLIS CONVENTION

FOLLOWING is an almost complete list of abstracts of papers which were presented at the Indianapolis Convention. The greater part of these papers will appear in TRANSACTIONS during the year.

W. G. CALKINS, Metallurgist, Detroit Twist Drill Co., Detroit, Mich. Paper: *"Notes on Forged High Speed Milling Cutters."*

Abstract:

1. Necessity for a superior grade of milling cutter.
   a. High speed steel specifications; chemical and physical.
   b. Superiority of 18 per cent tungsten high speed steel for drill manufacture.
2. Standard methods of manufacture of milling cutters.
   a. Cutting direct from bar stock.
   b. Upset or method of forging in recessed dies.
3. Structural conditions existing in high speed steel.
   a. In the ingot.
   b. In the billet.
   c. In finished bar stock; large and small rounds.
   d. Carbide segregation.
4. Structural condition in cutters made from large high speed rounds, illustrating coarse crystalline condition indicative of lack of sufficient reduction and mechanical working.
5. Structural condition in cutters upset from bar stock in recessed dies showing fine grained compressed condition existing at periphery.
6. Effect of forging high speed cutter discs between flat hammer dies.
7. Modern design for efficient high speed side milling cutters.
8. Results of milling test; forged versus bar stock cutters at equivalent rates of feed and speed cutting forged chrome nickel blocks of 230 Brinell hardness.

A. H. d'ARCAMBAL, Metallurgist, Pratt & Whitney Co., Hartford, Conn. Paper: *"Physical Tests on High Speed Steel."*

Abstract: Transverse tests at room temperature and tensile tests at temperatures ranging from room temperature to 1200 degrees Fahr., were conduced on two types of high speed steel, namely, the 18 per cent tungsten, 1 per cent vanadium type, and the 14 per cent tungsten, 2 per cent vanadium grade. The specimens were given different hardening treatments, and after being tested, the fractures were examined, samples file tested, and micrographs made on samples given the various heat treatments.

The transverse tests showed that samples quenched from a high temperature and drawn to 1100 degrees Fahr. possessed the necessary hardness and gave a high fiber stress, showing almost double the strength of specimens quenched from the same temperature and not drawn. Quenching into a bath at 1100 degrees Fahr. and not drawing, gave about the same fiber stress and exactly the same microstructure as samples quenched into oil and not drawn. Several specimens in the undrawn condition could not be tested, due to the presence of grinding cracks caused by strains in the material.

Tensile test specimens, quenched from a high temperature, and drawn to 1100 degrees Fahr., showed the maximum tensile strength when pulled at 600 degrees Fahr. Specimens quenched from the high temperature and not drawn, gave about 70 per cent of the tensile strength of samples quenched from the same temperature and drawn to 1100 degrees Fahr. before being tested at room temperature. Specimens given the high quenching treatment, but only drawn to 450 degrees Fahr., possessed only a slightly

higher tensile strength than specimens in the undrawn condition.

The higher vanadium type of steel gave lower transverse and tensile readings than the 18 per cent tungsten grade. This was due to some extent to the former type of steel not standing as high a quenching temperature as the higher tungsten type of steel, thus being slightly overheated, as shown by the fractures.

A. W. F. GREEN, Metallurgist, John Illingworth Steel Co., Philadelphia, Pa. Paper: *"Providing Properly Rolled Tool Steel for the Steel Treater."*

Abstract: A discussion of the production of tool steel. The chief consideration of the steel mill is the production of a tool steel or steels which will be uniform and meet the repeated demands of the consumer. This can be accomplished by the correct supervision of the mechanical working and heat treating of the material before it leaves the steel mill. The steels discussed are straight carbon tool steels, a few of the alloy steels with the exception of high speed steel.

Hammering of the steel is considered and the process is divided into two operations. The first of these is cogging down to a size and shape which can be readily used in the steel mill or under smaller hammers. The second is the finishing temperature. The cooling of the steel after hammering is discussed in an effort to show that the best tool steel is produced by applying special heat treatment to the finished pieces rather than by allowing the pieces to cool in the air, or in lime, ashes, etc., from the finishing temperature.

Rolling of the steel is considered and emphasis is placed on the need of care in heating for rolling and the finishing temperature of the steel as it leaves the mill. Efforts are made to establish the depth to which the rolling and hammering effect the structure of the steel and several drawings are shown, illustrating this point.

The conclusions drawn are that by proper supervision of materials and processes entering into the production of tool steel, together with consideration of the human element, that it is possible to produce a uniform grade of tool steel which is best suited to the particular users of the steel. The paper is illustrated by photomicrographs and drawings.

L. K. MARSHALL, Metallurgist, North East Electric Co., Rochester, N. Y. Paper: *"Tool Steel Manipulation."*

Abstract: The paper presented deals with the most important points met with in the scientific heat treatment of tool steel. Emphasizing that specialization in the heat treatment of tool steel is as important as specialization in production methods. Methods of handling the product of a tool room are discussed. All raw stock is checked to make sure that it will respond to heat treatment. The use of the spark test in checking types of steels used is described. Such points as design, annealing, and plugging of holes must be considered before the work enters the furnace. Breakage and warpage are caused by uneven heating in the vicinity of the critical range. Procedure in use of the electric furnace is followed through. Badly strained pieces are preheated to around 900 degrees Fahr. Work is placed in furnace the temperature of which is below the critical range of the steel being treated. The work is never allowed to become cold in the quench. Tempering is done immediately. Mechanical characteristics of the heat treated product are checked before delivery back to the tool room. The heat treatment of high speed steel in the electric furnace is described. The optical pyrometer is used. Summary.

M. H. MEDWEDEFF, Met. 5014 Weseley Ave. Howard Park, Baltimore, Md. Paper: *"Heat Treatment and Uses of High-Speed Steel."*

Abstract: The various steps in the heat treatment of tool steel are taken up and discussed in detail. Production methods of heat treatment are also taken up.

Attention is called to the indiscriminate use of high speed tools

for both roughing and finishing operations and the fallacy of this procedure is pointed out.

T. HOLLAND NELSON, Steel Works Mgr., H. Disston & Sons, Philadelphia, Pa. Paper: *"A Comparison of American and English Methods of Producing High Grade Crucible Steels."*

Abstract: The above paper deals with the Tool Steel Industry, commencing as an introduction with the days prior to the introduction of the Crucible Steel Furnace. The method of producing Shear and Double Shear Steel is detailed and a fine example of an old 18th Century Hammer under which Shear and Double Shear was made a 100 years ago is reproduced in the form of a lantern slide.

The author compares the English coke hole furnaces and clay pots with the regenerative American gas furnaces and plumbago pots and shows many striking contrasts in methods of production. Interesting details are given of the relative mixes of the Sheffield clay pots, the life of the furnaces and the general routine of our competitors in England.

In the general deductions the author claims that although the object is the same in both countries the method of production differs in many respects and hopes that his paper may give some of those interested a few points from the Sheffield industry which could be readily adapted in American practice with ultimate gain in the quality of the finished article.

The author frankly praises the American methods of production but equally frankly points out how some of the natural resources in England, and apparently minor details affect the finished product.

A. S. TOWNSEND, Chief Chemist, Cleveland Twist Drill Co., Cleveland. Paper: *"The Effect of Tungsten Content on the Specific Gravity of High Speed Steel."*

Abstract: The effect of tungsten content on the specific gravity of high speed steel is discussed and figures are given which show that the specific gravity increases directly as the tungsten content increases, other elements being constant. This rule holds for annealed chrome-tungsten-vanadium steels of the most common type. A simple and rapid method for determining the approximate tungsten content of steels of this type is proposed and explained in detail. The apparent specific gravity is determined and from this result the percentage of tungsten is calculated directly. A table is given showing the tungsten content corresponding to a given specific gravity.

R. L. DOWDELL, Instructor of Metallography, University of Minnesota, St. Paul, Minn. Paper: *"Reclaiming High Carbon Gears"*

Abstract: A tractor company turned out a large number of splined jack-shaft gears which with ordinary heat treatment were so hard and brittle that they would fracture on being tapped with a hammer.

Microscopic examination revealed the fact that instead of being lightly carburized they had been very heavily cased. The core should have run 0.20 per cent carbon and in many cases it ran 0.75 per cent.

A heat treatment was worked by which the core of these gears was rendered soft and tough and the outside made sufficiently hard for the purpose for which they were intended.

Photographs and photomicrographs are given showing the structure of the samples treated.

J. P. GILL and L. D. BOWMAN, Metallurgist and Asst. Metallurgist, Vanadium Alloy Steel Co., Latrobe, Pa. Paper: *"Metallography of High Speed Steel."*

Abstract: A discussion and review is given of the work of previous investigations on the same subject.

A discussion illustrated with slides is given of the critical points in highspeed.

A microstructure of high speed steel may be developed by

using a 1 per cent to 4 per cent nitric acid solution, an alcoholic solution saturated with picric acid, a 10 per cent solution of hydrogen peroxide and sodium hydrate, an alkaline solution of ferricyanide, and by heat tinting. Illustrated.

The microstructure of hardened and tempered high speed steels bear such a close resemblance to carbon steels in the hardened and tempered state that we are justified in using the same nomenclature. Illustrated.

The exact chemical composition of the matrix and of the embedded carbides or tungstides has not been conclusively proven.

The globules or beads as embedded in high speed steel are of a complex but similar chemical composition, and in view of the evidence presented probably should be called tungstides.

The larger percentage of the chromium is contained in the matrix of the steel which at high temperatures seems to give it a greater dissolving power.

A proportionally greater amount of tungsten is contained in the embedded tungstides than in the matrix.

The tungstides bear evidence of being of a eutectic composition.

The distribution of the carbides or tunstides in high speed steel is not only dependent on the amount and manner of the reduction of the ingot, but also upon the casting temperature and rate of cooling of the ingot.

Secondary hardness is a natural phenomenon and is dependent on the carbon, tungsten, chromium content.

N. B. HOFFMAN, Metallurgist, Colonial Steel Co., Pittsburgh, Pa. Paper: *"Ghost Lines and Grain Elongation in Hot Rolled and Cold Drawn Low Carbon Steel Wire."*

Abstract: This paper was prepared to try to show the occurence and difference between an elongated grain structure due to cold work, and a "ghost line".

I have first taken up elongated grain structures and have endeavored to show the comparison and proofs by submitting micrographs of drawn material after each draft, from one to ten. Then heat treating the grain elongated brittle wire, to show the complete crystallization of the grain structure without any inclusions of sonims. A section of wire is also shown containing the internal "cup" fracture due to over drawing and cold work.

The second wire was heat treated containing "ghost lines" and shows the ferrite grain structure breaking up and recrystallizing, but still retaining an area of sonims high in phosphorus and sulphur running through the grain structure and producing lines of weakness in the metal. Unusual grain growth is also shown caused by them holding phosphorus in solid solution Stead's Copper Reagent is used to show the outline of the "ghosts" due to the fact that areas low in phosphorus are precipitated with copper first, and as soon as the areas low in phosphorus are coated, the specimen is washed and micrographed, showing the outline of the "ghosts" high in phosphorus, to which the copper has not adhered.

I. H. COWDREY, Professor of Mechanical Engineering, Massachusetts Inst. Tech., Cambridge, Mass. Paper: *"The Efficacy of Annealing Overstrained Steel."*

Abstract: Steel is composed of granules of crystalline material inclosed in thin envelopes of non-crystalline or "Amorphous cement." This "amorphous cement" is hard and strong but brittle, and tends to impart properties to the metal in proportion to the quantity present.

During overstrain motion occurs between adjacent portions of the granules, which results in the transformation of some of the originally crystalline metal into the amorphous state. Hence, over strained steel becomes harder and more brittle hence less

resistant to shock. These are undesirable properties. It is customary to anneal many steel parts periodically.

Tests have been made to prove the efficacy of such treatment and the results lead to the following conclusions:

1. Overstrain of metal when its temperature is below the transformation range, results in the production of undesirable properties tending to render the metal unfitted to withstand sudden and shock loads.

2. If possible such effects should be eliminated for the safety of those using devices which have been so abused.

3. Proper annealing suffices to completely restore the normal properties of low carbon steel even after the most severe overstrain.

L. S. COPE, Metallurgical Engineer, Dannemore Steels, Inc., New York. Paper: *"Coarse Grained Forgings; Their Detection and Correction."*

Abstract: Many forgings fail due to the fact that they possess a very coarse grain structure. The manufacturer of the forgings blames the steel maker for this condition while the steel manufacturer in turn blames the heat treater. As a matter of fact it is the forger who is to blame in a great many cases.

The forging process is described in detail and the factors governing the grain size of the finished product are considered.

Methods of detecting coarse grained forgings are next taken up. Several well known methods are possible but all involve the destruction of the forgings. The writer, however, has hit upon a method which does not destroy the product and which may be used on a production basis. It consists in dipping polished portions of the forgings in dilute HNO_3 and noting the appearance of the wiped surface. This, however, does not put a stop to the production of coarse grained forgings.

Coarse grained structure in forgings may be greatly reduced by (a) the use of annealing and normalizing operations on pieces which must be heated to very high temperatures to properly carry out the forging process and (b) the intelligent designing of forging furnaces. These matters are discussed in detail.

E. J. JANITZKY, Metallurgist, Illinois Steel Co., South Chicago, Ill. Paper: *"A Contribution to the Problem of the Influence of Mass on Heat Treatment."*

Abstract: The present paper is a mathematical analysis of the test results obtained in an investigation conducted on 0.45 per cent carbon steel by the British Engineering Standards Association.

By application of mathematic principles to the above mentioned data it is possible to correlate hardness with the diameter of the heat treated bars both in the quenched and the drawn condition. From the equation thus established it is possible to predict what the hardness of bars of any given diameter will be when given the heat treatments used in these experiments.

T. D. LYNCH, & W. J. MERTEN, Met. Engrs. Material & Process Eng. Dept., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"Tests Showing the Effect of High Temperatures on Malleable Iron."*

Abstract: This paper describes an experiment carried on relative to annealing malleable iron which shows that white iron must be heated above its critical range in order to properly malleablize and that iron high in sulphur shows a much higher critical range than the lower sulphur iron. It also described tests covering the heating of malleable iron for the purpose of straightening warped castings and demonstrates that this can be done provided the temperature is kept below the critical range.

W. J. MERTEN, Met. Engr., Westinghouse Electric & Mfg. Co., Paper: *"A Coiling and Heat Treating Plant for Helical Springs."*

Abstract: The paper forcibly points out the necessity for utilizing adequate coiling and heat treating processes if a high standard in

spring performance is to be attained.

A detailed discussion is given of a plant in which the spring materials are constantly under technical control, without increasing the cost over that of springs now produced by antiquated methods.

W. P. PRIESTLEY, Supt. of Hot Metal Div., U. S. N. O. P. Charleston, W. Va. Paper: *"Fracture Test on Steel to Determine its Quality."*

Abstract: In a short article of less than one thousand (1000) words, a description is given of an inexpensive fracture test for steel forgings, blooms, billets, or bar stock, for the purpose of determining flake, slag, blow holes, or pipe in the steel.

Photographs showing specimen discs are furnished.

Results are also furnished of physical test bars which corroborate the data and information disclosed by the fracture tests.

W. R. WARD, Metallurgical Engineer, Lyells, Va. Paper: *"Miscellaneous Heat Treating".*

Abstract: The article touches on the following points:

A comparison of quantity production and miscellaneous heat treating.

Difficulties in treating small quantities requiring pack hardening.

Substituting a hardening steel in the place of mild steel used in pack hardening.

Warping and tolerances.

Protecting small parts of large tools when heated.

Modern instrument and the human element.

Work of skilled treaters.

Fractures and Metcalf bars.

Sand blasting tools.

Tempering.

Getting acquainted with the fellow who uses your treated work.

Cemented high speed tool bits on cheap steel shanks.

The varied work handled.

W. H. WHITE, Supt. of Melting Shops. U. S. N. O. P. Charleston, W. Va. Paper: *"Heat Treatment of Steel Castings".*

Abstract: This paper touches on the necessity of the steel treater to familiarize himself with the melting and shaping of steel, that further knowledge may be imparted to him in the execution of his profession; the classification of castings as to composition and size; the value of good records through all operations and inherent defects that should be studied for the determination of certain treatments; the use of scientific instruments and certain simple tests that assist in treatment determination.

C. M. CAMPBELL, Supt. Pioneer Alloy Products Co., Cleveland, O. Paper: *"Do Alloy Carbonizing Boxes Pay?"*

Abstract: The factors which tend to increase the life of carbonizing boxes are:

1. Critical points at or below average atmospheric temperatures.
2. Low co-efficient of expansion and contraction at high temperatures.
3. Good elastic limit and ductility at high temperatures.
4. Tendency to resist carbon absorption up to and including temperatures of carbonization of steel.
5. Resistance to oxidation.

The alloy possessing most of these features is one having a nickel base but this is very expensive.

Several attempts have been made to produce a less expensive alloy from an iron, chromium base but thus far these have not been very successful.

The use of the alloy carbonizing box in the jobbing and the specialty shop is discussed both from the standpoint of shop practice and from the standpoint of cost.

H. H. HARRIS, Pres., General Alloys Co., Chicago, Ill. Paper: *"Design of Heat Treating Containers."*

Abstract: The design of carbonizing containers is one of the most vital features of the pot and box problem. Furnace capacity, heating time, fuel bills and uniformity of product are largely determined by the design of the container. The ratio of carbonizing compound to pounds of steel carbonized is directly controlled by the design of the container.

Carbonizing containers should be designed with the following points in mind:

1. The dimensions of the parts to be treated. 2. The dimensions of the furnace. 3. The number of parts to be placed in each container, and the number of containers to be placed in each furnace. 4. The weight, wall section and conductivity of the containers. 5. The flange design and method of sealing. 6. Legs for heat circulation and lugs for handling. 7. Methods of handling. 8. Methods of cooling.

The dimensions of the parts to be treated limit the inside dimensions of the container, and the dimensions of the furnace limit the outside dimensions. The number of parts can generally be varied and packed either vertically, horizontally or in combination. The number of boxes can generally be varied and placed in different combinations in the furnace. It is desirable to get the largest possible cubical box content into the furnace with due regard to flue space for heat circulation.

This paper deals with various designs of containers, methods of sealing, etc., and with the variables that are affected by container design.

V. E. HILLMAN, Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"The Efficiency of Various Mixtures for Cyanide Hardening and The Role of Nitrogen in the Process."*

Abstract: The author deals with the efficacy of cyanide hardening mediums. Curves have been plotted to show the depth of "case" incident to the use of the subject mixtures.

Several paragraphs have been devoted to cyanide containers, the fume nuisance and testing. The presence of nitrogen is discussed both from the standpoint of chemical and microscopic examinations. The micro-appearance of the unhardened case is described in detail particularly with reference to the formation of a special constituent known as "Flavite."

W. I. McINERNY, Foreman Heat Treat. Armor Plate, U. S. N. O. P. Charleston, W. Va. Papers: *"Carburizing Heavy Sections."*

Abstract: A short paper on carburizing heavy sections four to thirteen inches in thickness, giving the results of different experiments in carburizing showing an increase in carbon or case from surface to a depth of two inches.

H. SCHAGRIN, Ch. Chemist, U. S. N. O. P. Charleston, W. Va. Paper: *"Carburization with Wood Charcoal."*

Abstract: In this article the effects of carbonization at temperatures varying from 1400 degrees to 2000 degrees Fahr. using wood charcoal only as carbonizing agent are brought out. Temperature control was effected by means of thermocouples inserted in the center of the boxes. Some chemical reactions attending carbonization are discussed. The experiments were carried on on a production basis in semi-muffle type furnace of the same size regularly used for production work.

It is concluded that for a normal rate of penetration of approximately 1/16 inch, and where this can be accomplished during a period of from one to one-half hours, wood charcoal will serve the purpose.

P. W. & E. B. SHIMER, Metallurgical Engrs., Easton Pa. Paper: *"Cyanamid in Liquid Case Hardening."*

Abstract: This paper amplifies and brings down to date the description by Professor Joseph W. Richards of "The Shimer Case Hardening Process" read by him before the New York Meeting of the American Institute of Mining and Metallurgical Engineers in February, 1919.

The process has now been in continuous and successful use for nearly five years.

The harmlessness of the gases evolved has been demonstrated by the collection and analysis of samples. They are a mixture of nitrogen, carbon monoxide and a little carbon dioxide; no trace of cyanogen could be collected from a sample of six liters. The carbon monoxide burns to carbon dioxide on the surface of the melt, leaving only perfectly harmless gases to escape into the air.

With carefully selected lump calcium cyanamid and the inert mixture of salts with which it is used case-hardening is done at the usual temperatures and, if desired, at higher temperatures, such as 1650 degrees Fahr. and even 1700 degrees Fahr. It is possible to get about 1/32-inch case in 1½ to 2 hours at the higher temperatures.

S. C. SPALDING, Metallurgist, Halcomb Steel Company, Syracuse, N. Y. Paper: *"Comparison of the Rate of Penetration of Carbon Into Various Commercial Steels Used for Case Carburizing."*

Abstract: Brief introduction and reference to standard authorities on the subject.

Types of steels investigated comprise plain carbon, cold rolled, chrome silico manganese, chrome vanadium, 3½ per cent nickel, 5 per cent nickel, two types of chrome nickel and a chrome molybdenum.

Test bars were run for periods of 5, 10, 15, 20, 25, 30, 40, 50 and 55 hours at 1600 degrees Fahr. and 1700 degrees Fahr. allowed to cool in pots then the depth of case measured by the microscope. Some of the typical test pieces were given different heat treatments to show their effects on case and core. Time penetration curves for each temperature and each steel are given with a combined sheet showing all steels plotted to same coordinates for one temperature. Complete series of photomicrographs of all steels at different times and temperatures are given with explanatory discussion.

A. E. BELLIS, Pres. Bellis Heat Treating Co., New Haven, Conn. Paper: *"Influence of Heating Medium on Structural Changes in Steel."*

Abstract:

1. Metallurgical objectives in treating steel.
   Importance of rate of heating and cooling, and time effect in hardening and tempering.
2. Consideration of properties of gaseous, liquid and solid heating medium, specific heats, heat conductivity and heat convention, "Quantity" of heat.
3. Particular considerations of different liquid heating media and their effect on transferring heat to different steels.
4. Practical application of these facts to treatment of high speed steel.
   A method for complete transformation in hardening.
   The "quantity" of heat required for transformations.
   Effect of rate of cooling.
   Obtaining maximum rate at various temperatures.
5. Tests and performance records of cutting tools.

A. A. BLUE, Metallurgist, Duff Mfg. Co., Pittsburgh, Pa. Paper: *"A Successful Bonus System Applied to Heat Treating."*

Abstract: The requirements for a successful bonus system are

(1) the figures must be easily and cheaply calculated and they must be accurately obtained; (2) the flexibility of the organization must not be greatly affected by such an installation; (3) it should cover a wide range of products; (4) it must obtain co-operation between all employes, those on the same shift and those on all shifts; and (5) complete records must be kept of all details, preferably by the men themselves.

The system used by one eastern manufacturing concern is based on both quality and quantity demands. The bonus is allowed to heaters on the basis of (a) the accuracy of control of furnace temperatures and (b) time required per heat. The bonus is allowed to helpers on the basis of material handled per unit time. The unit used is pounds per furnace hour.

The system has proven very satisfactory both to employers and employes.

J. WALTER BRESSLER, Philadelphia, Pa. Paper: *"System of Records for Metallurgical Departments."*

Abstract: An accounting system is described by means of which the inspection and chemical analysis of each lot of steel received is recorded. The system also includes the record of heat treatment, physical tests and final inspection. These records are so arranged that they may all be conveniently filed with the orders for finished products.

The various printed forms used in this system are included in the paper.

W. E. JOMINY, Met. Studebaker Motor Car Co., Detroit, Mich. Paper: *"The Selection of Steels for Automobiles."*

Abstract: The present paper is divided into two parts namely:

(a) Factors governing the proper selection of a steel for a given part.

(b) Steel commonly used in present day practice.

In section (a) the various factors entering into the selection of steel are considered such as elastic limit, ductility, resistance to wear, machinability and cost.

In section (b) twelve types of steel are described which cover every need of the automobile engineer in designing a motor car.

E. W. PIERCE, Metallurgist, Maxwell Motor Car Co., New Castle, Ind. Paper: *"Buying Steel on Closer Carbon Limits."*

Abstract: This paper consists of an argument for the buying and selling of steel on a five point carbon limit, instead of the present method of a ten point variation. It deals with the argument from the standpoint of the fabricator who is required to forge, heat treat and machine for a finished product.

Particular attention is given to shop troubles arising from heat treated material of a wide variation, as regards production and costs. It covers difficulties arising in case hardening as well as heat treating when traced to varying carbon content. Mill practice to produce this desired limit is suggested.

C. F. SMART, Asst. Ch. Metallurgist, Ingalls-Shepard Div. Wyman-Gordon Co., Harvey, Ill. Paper: *"Steel Is Steel."*

Abstract: Instances are given illustrating losses resulting from use of steel of wrong composition, due to improper segregation of stock. Data, summarized and plotted, from over six hundred tests covering more than one hundred heats of 1045 steel shows a wide distribution of physical property values obtained in the application of like heat treatment to stock of similar composition. This, with other tests and a study of Brinell tests on many thousands of heat treated forgings leads to the belief that about 70 per cent practice can be consistently maintained on carbon steel forgings from mixed heats, heat treating to a Brinell range of 0.3 mm.; while if such stock be checked by chemical analysis, segregated, and treated by individual heats, according to treatment

determined by previous metallurgical tests, a practice of 99 to 100 per cent can be maintained. Such evidence fortifies the conclusion that for utmost of profit and satisfaction steel requires study and investigation, separation and selection, carefulness in handling, judgment in choice of stock, determination of proper treatment and accuracy in carrying out that treatment.

W. P. WOOD, Professor of Chem. Engineering, University of Michigan, Ann Arbor, Mich. Paper: *"A University Course in Metallurgical Engineering."*

Abstract: A four year course leading to some such degree as Bachelor of Science in Metallurgical Engineering is presented. The object in mind has been the preparation of students not so much in the mining and mill end of metallurgy as in that part of the science which has to do with the final fabrication and preparation of metals and alloys for use. This is largely the result of the fact that the writer's work and experience has been in the vicinity of the center of the automobile industry where the object stated above would have particular application, and because of the fact that most of the older courses in metallurgy put no more stress upon the final preparation than upon the mining and mill end of the industry.

The writer's defense of this procedure is the belief that any university, particularly state universities should serve the part of the country which is contributing most largely to their support and that the courses taught therein should place emphasis upon those phases of industry which are most important in the territory which the university serves.

H. F. WOOD and F. G. MILLARD, Ch. Metallurgist, and Supt. of Finishing Dept., Ingalls-Shepard Division, Wyman-Gordon Co., Harvey, Ill. Paper: *"Determination of Heat Treating Costs."*

Abstract: Paper covers the importance of proper cost determination in the heat treating department, and the importance of supplying foremen with proper monthly reports.

Gives a detailed analysis of costs, bringing out the items that constitute burden and shows how the burden is distributed on the equipment in the form of furnace hour rates.

The method of collection of cost data is given in detail as well as the method of determination of actual costs from the data collected.

Paper is finished by discussion on the effect of proper cost analysis in the heat treating department.

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper: *"Tensile Properties of Some Structural Alloy Steels at High Temperatures."*

Abstract: The report gives results of determination of tensile strength, proportional limit, elongation, reduction of area and strength at fracture throughout the range 20 degrees to 550 degrees Cent. for four steels containing about 0.38 per cent carbon, as follows:

(a) plain carbon steel.
(b) 3½ per cent nickel steel.
(c) 3 per cent nickel, 1 per cent chromium steel.
(d) 1 per cent chromium, 0.20 per cent vanadium steel.

Brief reference is made to the type of fractures obtained in testing steels at various temperatures and particular attention is paid to comparison of the tensile properties of these alloys at 550 degrees Cent.

M. A. GROSSMAN, Metallurgist, Electric Alloy Steel Co., Youngstown, O. Paper: *"The Toughness of High Speed Steels as Affected by Their Heat Treatment."*

Abstract: Data are presented constituting the results of toughness tests on two high speed steels of common analysis. The tests were carried out on an impact machine of the Charpy type, on test bars which resembled the standard Charpy bar, unnotched.

A considerable number of test pieces were hardened and

drawn, covering the quenching range from 1700 to 2250 degrees and the drawing range from no draw to 1100 degrees. For each quenching temperature a series of test pieces was drawn at all the drawing temperatures. It was found that there is a certain quenching temperature slightly below the proper hardening range for which the steel is brittle on being quenched and acquires no toughness on being drawn up to 1100 degrees. Below this quenching range, drawing imparts toughness but lowers the hardness. Above that range, drawing at 1100 degrees imparts toughness while at the same time developing secondary hardness. The toughness tests and the hardness tests were carried out on the same test pieces.

Curves are given showing the changes in toughness for the different heat treatments and the change in scleroscope hardness for those heat treatments. The data show:

(1) That the development of secondary hardness in the proper hardening range is accompanied by an acquiring of toughness which may properly be called "secondary toughness," and

(2) that just below the proper hardening range there is a range of temperature which, while giving quite good hardness, results in the steel being brittle and remaining so even with subsequent drawing to 1100 degrees.

C. M. JOHNSON, Director of Research, Park Works Crucible Steel Co. of America, Pittsburgh, Pa. Paper: *"Some Alloy Steels of High Elastic Limit, Their Microstructure and Heat Treatment."*

Abstract: The report gives the results of heat treatment and physical tests on a series of alloy steels of high elastic limit. The following steels were investigated:

1. A nickel-silicon steel.
2. A nickel-silicon steel containing small amounts of chromium and vanadium.
3. Same as No. 2 but containing small amounts of titanium.
4. Same as No. 2 but containing small amounts of zirconium.
5. Same as No. 2 but containing small amounts of tungsten.
6. Same as No. 2 but containing small amounts of molybdenum.

Micrographic studies were also made on these steels and are included in the report.

G. C. McCORMICK, Asst. Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"A Discussion of Uranium and Allied Elements."*

Abstract: The paper discusses the beneficial effects of uranium firstly as a scavenger and secondly as an alloying element.

The writer presents a Metallurgical Provision Chart which groups the alloying elements according to the location of their melting points and according to the manner in which they augment the physical properties of steel.

The chart presents three characteristic groups which show omissions which appear to be prophetic of what may be expected in the line of future metallurgical developments.

H. STYRI, Chief of S. K. F. Research Laboratories, Philadelphia, Pa. Paper: *"Heat Treatment of Chrome Steel for Ball Bearings."*

Abstract: The material used in the production of balls is described.

The proper conditions for hardening of this steel is discussed and the phenomena generally accompanying hardening are described. Special attention is given to the effect of varying the cooling rate. Several very interesting abnormalities in hardening are described.

A considerable number of photomicrographs are shown illustrating the above mentioned features.

J. S. VANNICK, Metallurgist, Research Laboratory, Department of Agriculture, Washington, D. C. Paper: *"The Mechanical Properties of Some Chrome Vanadium Steels."*

Abstract: 1. The mechanical properties such as tensile strength and

hardness of a series of chrome-vanadium steels was determined. The series were divided into 3 groups as follows:

	C	Va	Cr. Varying from
Group I	.30-.40	.14-.20	0.0 to 14.5
	C	Cr	Va varying from
Group II	.30-.40	1.0	0.0 to .65
	Cr	Va	C varying from
Group III	1.0	.20	.15 to 1.20

2. In group I, the increasing chromium gradually increases the tensile strength and hardness up to 2 per cent. Cr. Above 2 per cent Cr. the tensile strength increases rapidly, but the ductility is slightly decreased. In the heat-treated condition the same effects are greatly intensified.

3. In group II, the effect of vanadium within the range investigated is not marked in the annealed steels. In the heat-treated set, a sharp increase in tensile strength appears as vanadium is increased from .30 to .65 per cent. The ductility of this steel (.65 Va) is slightly lowered.

4. In group 4, an increase in carbon increases the tensile strength and lowers the ductility of the annealed steels. In the heat-treated specimens a similar effect occurs up to .60 per cent C. at 1.20 per cent C. (carbon) the tensile strength falls and the steel becomes brittle.

5. From a summary of the data, chromium up to 2 per cent improves the tensile and hardness properties of a carbon-vanadium steel; vanadium exerts no appreciable effect in a chrome-carbon steel; carbon up to .60 per cent increases the tensile strength of a chrome-vanadium steel; at 1.20 per cent a preceptible decrease in strength and ductility is noticeable.

6. The results of fracture tests made to determine the quenching ranges are compared to the position of the critical points of the steels as determined by thermal analyses.

7. The microstructure of the different steels is described and micrographs typical of the steels in the heat treated condition are included.

R. M. BIRD, Metallurgist, Bethlehem Steel Co., Bethlehem, Pa. Paper: *"Standardization of Methods Leading to Comparative Physical Properties of Alloy Steels."*

Abstract: There is a large and ever increasing demand for accurate knowledge on the matter of proper heat treatments and physical properties of alloy steels. The Steel Standards Division of the American Society of Automotive Engineers has done a great deal on the subject and their efforts will be of great value when complete. However much remains to be done.

At a plant of one of the large steel companies data of this sort has been accumulated for many years. A very complete procedure has been worked. After proper inspection, 4-inch x 4-inch billets are rolled into 1-inch rounds. These in turn are inspected and analyzed after which critical points are run on them. The bars are then normalized and given a wide range of heat treatments after which they are pulled on a testing machine. Both Brinell and scleroscope hardness are taken. The results are plotted on convenient forms.

Data on bars larger than the 1-inch rounds are as yet not available.

A. M. COX, Asst. Metallurgist, R. D. Nuttall Co., Pittsburgh, Pa. Paper: *"The Abrasive Qualities of Plain Carbon and Alloy Steels."*

Abstract: The paper covers a large number of tests that have been made on steels of different quality and different heat treatment, to determine the relative wear as effected by steels that rub, one against the other.

The material used in the abrasive tests were subjected to chemical, static tension, and brinell hardness tests. Microphotos were also taken of one specimen from each test group.

The steels tested were plain carbon and chrome nickel. In the annealed, heat treated and carbonized condition. The test

results indicate that:—The greater the density and hardness, the greater the abrasive resistance. Also that the ordinary tension and brinell tests are not a reliable index to the abrasive qualities of a material.

The carbon steel showed more uniform results than the chrome nickel steel and greater average wear, with similar density and hardness.

H. J. FRENCH and W. G. JOHNSON, Physicist and Asst. Physicist, Bureau of Standards, Washington, D. C. Paper: *"Effect of Heat Treatment on the Mechanical Properties of One Per Cent Carbon Steel."*

Abstract: The effects of varying time-temperature relations in heat-treatment on tensile and impact properties, hardness, and structure of one per cent carbon steel have been studied, including (a) effect of temperature variations in hardening (b) time at hardening temperatures both above Acm and between the Acl and Acm transformations (c) effects of tempering steel hardened in different ways and effects of "soaking" just under the lower critical range (d) comparison of oil and water hardening for production of definite strengths.

H. A. HOLZ, Pres. Holz & Co., New York. Paper: *"Recent Researches on the Elastic Limit."*

Abstract: To the constructive engineer the most important physical property of steel is its "limit of proportionality" or, as this limit is alternatively called, the "true limit of elasticity." Up to this limit the extension is proportional to the load which produces it. Beyond this limit the extension increases at a greater rate than the load, and the material no longer shrinks to its original dimensions after the load is removed, but retains a permanent set. The "yield load" determined in the usual routine testing of steel is not the limit of proportionality, nor is this limit any constant fraction of the yield load.

The reason why the limit of proportionality has not been one of the data included in the usual routine and commercial tests of steel is that by the methods and instruments heretofore available for real accurate work, the observations are tedious and the time required in making these observations and subsequently alotting them is so considerable that the cost has been prohibitive.

The limit of proportionality and other elastic constants can now be accurately determined, automatically and so quickly that there is no reason why these important constants should not be included in the routine testing of steel.

Our present "tensile tests" are crude and do not disclose defects in steel which are often of great importance, such as notch-brittleness. The instrument described produces automatically accurate and complete "load-extension diagrams" and differentiates clearly between steels of different impact values. It seems that the diagrams obtained by this apparatus will also show the positive value of the fatigue limit.

L. W. WILD, Pres., Wild Barfield Co., London, England. Paper: *"Influence of Heat Treatment on the Magnetic Properties of Steel."*

Abstract: The object of the investigation reported in this paper was to determine the changes in the intensity of magnetization and coercive force when samples of hardened steel were reheated to various temperatures and slowly cooled.

The following samples were tested: Swedish iron, low, medium and high carbon steel, and chrome, nickel and tungsten alloy steels. After quenching these samples were reheated to varying temperatures (from 100 degrees Cent. to 1100 degrees Cent.) and the magnetic changes determined.

The results are plotted as curves.

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper *"Effect of Heat Treatment on Mechanical Properties of a Carbon Molybdenum and a Chrome Molybdenum Steel."*

Abstract: Thermal transformations of a carbon molybdenum

steel containing 0.20 per cent carbon and about 1 per cent molybdenum and a chromium molybdenum steel of the type 0.27 per cent carbon, 0.9 per cent chromium and 0.5 per cent molybdenum are given for various temperatures of heating and rates of cooling.

The effects of the following variables on the mechanical properties and structure of these steels are discussed.

(a) Variations in normalizing temperatures.

(b) Variations in temperature from which the steels are hardened.

(c) Effects of tempering at various temperatures. Comparison of various methods of heat treatment for the production of definite tensile strength and impact values in the carbon molybdenum steel are also given.

W. H. BRISTOL, Pres., Bristol Co., Waterbury, Conn. Paper: *"Automatic Compensation for Variations in Temperature of Cold Ends of Thermo Electro Pyrometers."*

Abstract: The objects of this paper are to call attention to the importance of properly taking into account the effect of the variations of cold end temperatures of the thermo-electric couple and to describe with illustrations a method of automatic compensation for atmospheric changes of temperature that may occur at the point where the cold end of a thermo-electric couple of a pyrometer is located, so that the readings of the instrument will be correct and independent of such temperature changes.

By means of lantern slides and moving pictures a demonstration will be given to show that the cold end of the thermo-electric couple of a pyrometer may be varied in temperature over a range of 100 degrees Fahr., and still automatically compensate for such a change giving correct temperature indications of the hot end of the thermo-couple, the same as if the cold end had been maintained at a constant temperature, when provided with the automatic compensating device.

E. D. CAMPBELL, Professor of Chemistry, University of Michigan, Ann Arbor, Mich. Paper: *"Some Brinell Hardness Measurements on Small Specimens."*

Abstract: The method of constructing and calibrating a light balance which may be readily substituted for the regular 500 kilogram balance of a standard alpha Brinell machine is described. When the light balance is used with a 2 millimeter ball and a 16 millimeter objective substituted for the 48 millimeter objective of a standard Brinell microscope, the image will appear exactly the same size as that which would be obtained with a 10 millimeter ball under 3000 kilos pressure.

By adding to the light balance, 21 kilos using the 5 millimeter ball and observing the impression with a 32 millimeter objective, the image will correspond with that which would be obtained with the same metal tested with a 10 millimeter ball under 500 kilos pressure.

With this attachment, hardness measurements may be made on quite small specimens with the same accuracy and almost as easily as can be done on large samples working under standard conditions and the same tables of hardness numbers may be used. Illustrations showing the influence of carbide concentration and rate of cooling on the hardness at opposite ends of small bars 6 millimeters square by 15 millimeters in length are given. The results confirming deductions previously made from differences in thermo electro motive potential measurements on similar bars.

KELLER, GEORGE, Sales Mgr. Brown Instrument Co., Philadelphia, Pa. Paper: *"Skipping the A. B. C's to Talk the X. Y. Z's of Temperature Measuring Instruments."*

Abstract: An interesting story is told that the profit in selling incandescent lamps made the Mazda possible. The profit enabled the manufacturer to maintain a research organization. As a result, the public gets three times as much light for the money today.

In the same way research has, in the last twelve months, since

the last show, contributed materially to the betterment of design of everything the steel treater used. A few striking examples are illustrated in this article such as a portable potentiometer with an 8-foot scale, the use of automatic signaling, the heat cycle controller, new cold junction compensation and a little further comment on what may be expected from the research laboratories of such groups of men as the instrument manufacturers.

R. W. NEWCOMB, Mgr., Charles Engelhard, Inc., New York City. Paper: *"A New Type Automatic Temperature Regulator; Its Application to Heat Treating Furnaces."*

Abstract: An automatic temperature regulator to be satisfactory, must possess the following qualities:

(a) Dependability, under which should be included accuracy, constancy, simplicity, and power.

(b) Flexibility, under which should be included adaptability to gas, oil, powered coal, and electric furnaces.

(c) Adjustability. It must be possible to adjust the range, speed and magnitude of control to cover a wide range and also diversified furnace and burner construction.

An instrument which, it is thought, fulfills these requirements is described in detail and its various possibilities discussed.

T. Y. OLSEN, V. P. Tinius Olsen Testing Machine Co., Philadelphia, Pa. Paper: *"Determination of Stiffness of Wire or Sheet Metal."*

Abstract: Methods of inspection of material going into springs has been very much of an approximate process up to the present. In as much as large quantities of spring materials are consumed every year it is highly desirable to have a reliable test to use on such material.

A testing machine which it is thought, fulfills the requirements for such a test, has been designed and is described in this report.

S. P. ROCKWELL, Metallurgist, Whitney Mfg. Co., Hartford, Conn. Paper: *"Testing of Metals for Hardness."*

Abstract: The object of the investigation presented in this report was to compare the results obtained by the Brinell, Sclerescope, and Rockwell hardness testers on various metallic products and under varying conditions.

The instruments were tested out on carbon and alloy steels under several conditions of heat treatment, on nonferrous materials of varying degrees of hardness and on the above materials in the form of tubes, rounds, etc.

The possibilities of converting the readings of any one of the machines over into terms of any of the others is taken up.

The results of tests are shown as curves.

C. UPTHEGROVE, Professor of Chemical Engr., University of Michigan, Ann Arbor, Mich. Papers: *"Note on the Small Brinell Machine."*

Abstract: The Baby Brinell machine is described. Its development has been described by Goodale and Banks in the Development of Brinell hardness tests on thin sheet brass.

This machine has been used for the testing of cartridge brass and other thin sheets, using a 1/16-inch ball and 15 kilogram load. The design does not limit the load or ball to the above sizes but is such as to allow ready substitution of other size balls or loads.

The operation, accuracy, uses and limitations are discussed.

T. F. BAILY, V. P. Electric Furnace Co., Alliance, O. Paper: *"Electric Furnaces for Heat Treating With Automatic Control."*

Abstract: The means by which automatic temperature control is obtained in electric furnaces may be divided into three classes:

(a) Control of the quantity of electricity going into the furnace.

(b) Automatic pyrometer control, which controls the movement of the material through the furnace.

(c) A time element device, making a movement of the material

through the furnace every so many minutes.

The first means of control is only practical on small wire wound furnaces as on large furnaces it would cause such violent fluctuation in power that the price of electricity would be excessive.

The second and third types of control have been found usable on large scale operations. They are free from the objections mentioned in the first case and have been found to give consistent results over a period of several years.

G. R. BROPHY, Metallurgical Engr., Indus. Furnace Dept. General Electric Co., Schenectady, N. Y. Paper: *"Calite; A New Heat Resisting Alloy."*

Abstract: An alloy containing Al, Ni, Fe, which will stand, without oxidation, temperatures up to 1300 degrees Cent. (2372 degrees Fahr.) This material is highly resistant to atmospheric corrosion and the action of acids (except HCl and H_2SO_4). In a concentrated sea salt solution spray at 100 degrees Fahr. this alloy retained a perfect polish after 100 hours. It is unaffected by molten NaCn, $BaCl_2$ or NaCl. Molten or vaporized S does not affect it appreciably.

Physical properties.

Melting p.—1500 degrees-1525 degrees Cent.
Sp. gr.—7.03.
Transverse strength.
1-inch square bar 12-inch sup't.—4250 pounds.
Electrical resistivity—112 ohms per cm^3
Heat resistivity—3.25x that of Ni.
Temp. Coeff.—0.00044

It is forgeable only when handled carefully and by special procedure. After repeated heating and cooling from 1000 degrees Cent. no change took place in dimensions, neither does repeated quenching from this temperature affect the metal.

Any shape which can be cast of steel can be as easily cast of Calite.

E. F. DAVIS, Sales Mgr. Celite Products Co., New York. Paper: *"Construction of Furnace Doors, Lining and Bases."*

Abstract: It is pointed out that furnace construction is one of the most backward branches of engineering science. The reasons for this are pointed out.

The three methods of heat transmission namely conduction, radiation and convection, are taken up and discussed in detail. The calculation of heat losses is taken up and developed fully.

The question of furnace construction is next considered and such questions as the relation of size to fuel consumption, the use of insulation in doors, linings and bases, etc., are discussed.

F. J. EVANS, Sales Eng. Surface Combustion Co., Springfield, Mass. Paper: *"High Pressure Gas and Its Application to Industrial Furnaces."*

Abstract: In the application of gas fuel to industrial plants there are three distinct systems in common use:

(a) Low pressure air and gas systems with two value control and manual proportioning.

(b) Low pressure air and gas system with single value control and automatic proportioning.

(c) High pressure gas system with single value control and automatic proportioning.

The first two systems are open to several objections among which are the fact that very large pipes must be used for the gas and individual blowers are necessary to supply the compressed air.

The third system is open to neither of these objections and in addition has many desirable features which are fully brought out in the article.

J. T. GOWER, Armstrong Cork & Insulation Co., Pittsburgh, Pa. Paper: *"What Insulation Will Do for the Heat Treater."*

Abstract: The benefits which are derived from the use of heat

insulating materials can hardly be over-estimated. A few of the most prominent of these are:

(a) Insulation increases the capacity of equipment with no increase in fuel consumption.

(b) Insulation makes temperatures more uniform in heated equipment.

(c) Insulation decreases the time required to bring equipment to the working temperature.

(d) Insulation, an many cases, lengthens the life of refractories by eliminating the necessity for over heating in the combustion chamber.

(e) Insulation makes more comfortable working conditions by reducing air temperatures around the heated equipment.

The various factors governing heat losses through conduction are discussed and formulated mathematically.

C. L. IPSEN, Designing Engr., General Electric Co., Schenectady, N. Y. Paper: *"The Electric Furnace as it Affects Over-all Cost of Heat Treated Parts."*

Abstract: In the development of steel treating furnaces there has been a progressive change from one form of heat source to another, starting with wood and going on through coal, oil and gas, to electricity. Each change has been to a higher priced fuel, indicating that there are factors more important than fuel costs in steel treating. A table is given showing the over-all cost of several heat treated parts and the percentage of this cost that is chargeable to fuel. A small improvement in quality, reduction in rejections or saving in subsequent operations will in most cases cited many times offset the increased cost of improved heat source.

Electricity is the ideal heat source for steel treating because (1) the temperature of heat source is only slightly higher than parts being treated, so that no part can be overheated; (2) absolute temperature uniformity can be maintained; (3) the human element is reduced by the use of accurate and reliable temperature control.

In the selection of any furnace first consideration should be given to cost and quality of finished part, as it will in most cases show that the highest priced heat source is the least expensive.

P. J. LAFORE, Industrial Eng., Boston Consolidated Gas Co., Boston, Mass. Paper: *"The Use of Gas Fired Furnaces for Heat Treating."*

Abstract: The paper speaks of the need of a suitable furnace in order to properly heat-treat steel, and outlines the more essential features of such a furnace. It compares coal, oil, electric and gas furnaces, bringing out the point that coal and oil are not satisfactory for most purposes. Electricity gives good results but is expensive and slow in coming up to temperature, but where the proper type of gas-furnace is used the results are very satisfactory.

It then goes on to describe some of the requisites of a good gas-furnace and the four general classes of mixing devices that can be used, viz., high-pressure gas system, in which all of the air is drawn in and mixed at the mixing device at the furnace; system where part of the air is mixed with gas away from furnace and is carried under pressure to the furnace where the remainder of the air is drawn in; low-pressure gas system where the air under pressure automatically admits and induces the gas, and the two-valve system where air under pressure inducts the gas by means of a mixing tee.

It then describes a gas installation in a manufacturing plant making jacks, and in a commercial heat-treating plant. In both cases the equipment is all gas, the first using the two-valve system, and the second, high-pressure gas, where all the air is drawn in at the mixing device at the furnace. It describes the kind of work done and the highly satisfactory results obtained.

G. M. LITTLE, Res. Engr. Div., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"An Electrically Heated Forging and Heat Treating Furnace."*

Abstract: The paper "An Electrically Heated Forging & Heat Treating Furnace" gives an account of the development of a resistance type electric furnace for high temperature work. In it is brought out the remarkable scarcity of materials suitable for constructing a satisfactory heating element or resistor—and the solution of this problem by the construction of a heating element composed of a pile of carbon plates clamped together under heavy pressure and surrounded by a blanket of hydrocarbon vapors.

It is pointed out that, in practically all the present forms of resistor type furnaces, it is not possible to crowd them so as to obtain a large output of heated metal, on account of the melting down of the refractories which support or back up the heating element. This problem was solved by suspending the heating element across the furnace chamber free from the walls or roof—and by the use of a top lining to the furnace chamber composed of bars of carbon covered with a thick layer of coke dust. This roof cannot be melted and is protected from oxidation by the same blanket of hydrocarbon vapors which protects the heating element.

The gene al description of the final form of a forging furnace of this type is given and some data as to the performance and cost of operation.

A paragraph is given to some interesting results obtained in a small experimental brass melting furnace which was constructed along the same lines as the forging furnace.

W. E. McGAHEY, Foreman, Heat Treating Large Guns, U. S. N. O. P., Charleston, W. Va. Paper: *"Heat Treatment of Large Forgings by Oil, Gas, and Electricity."*

Abstract: Definition of the term "Large Forgings" dividing them into two classes with respect to heat treated quality.

The value of uniformity in heating which is largely dependent upon temperature control and the defects that may result from non-uniformity.

Conditions governing temperature control and the difference in method of control for oil, gas and electric fired furnaces.

The burning and heating efficiency of oil and gas compared with electricity.

Comparative advantages and disadvantages effecting the cost and practicability of oil and gas fired furnaces versus electric.

A. F. MITCHELL, Supt. Heat Treating U. S. N. O. P., Charleston, W. Va., Paper: *"A Comparison of Conditions Entering Into the Operation of Oil and Natural Gas Fired Furnaces."*

Abstract: This paper deals with furnace selection, energy application, fuel mixers, fuel oil, natural gas and the human element is applied to industrial heat treating furnaces.

The information and suggestions are based upon practical experience in the heating of large masses up to fifty tons in weight.

The furnace selection deals with types of furnaces, combustion chambers, heating chambers and refractory materials.

The application of fuel energy is dealt with as applied today in industrial furnaces and suggestions are made for fuel conservation.

Under the heading of fuel mixers the writer calls attention to efficient and inefficient methods of mixing and burning fuels and calls attention to conditions that are to be desired.

The quality of fuel oils, installation required and conditions necessary to secure satisfactory results are briefly described.

Past experiences with regard to the use of natural gas in the industries is referred to and suggestions for its conservation where it is available, are made.

Suggestions are made which if applied would increase the efficiency of furnace operators.

J. WEAVER SMITH, Inds. Engr., Citizens Gas Co., Indianapolis, Ind. Paper: *"Gas Accessories for the Heat Treating Room."*

Abstract: In this article the writer offers a few practical sug-

gestions as to the use of some of the minor gas appliances. He discusses the different methods of heating liquids in large quantities, especially as applied to cleaning solutions, etc. He gives in detail the method of computing the amount of heat required to raise any liquid to a given temperature, and describes a method of heating not generally known which he claims is far more efficient than any other. The proper design and construction of both blast and atmospheric burners is discussed from an engineering standpoint in language that is practical and easy for the layman to understand, going back to the discovery of the Bunsen burner. The effects of improper design and construction are likewise given. The paper is illustrated by numerous lantern slides.

R. E. TALLEY, Ch. Engr., Geo. J. Hagan Co., Pittsburgh, Pa. Paper: *"Operating Data on Electric Furnaces."*

Abstract: The application of electric heating furnaces for scientific and experimental work during the past ten (10) years has been so general that their superior merits as a heating medium is well known to metallurgical men.

Due to the limited size of furnaces used for this class of work, however, the data obtained has been more in the nature of development of treatments rather than showing just what performance could be expected from larger units in commercial production.

It has only been within the past two (2) or three (3) years that applications of electric furnaces to heat treating on a production basis has become sufficiently widespread to permit of any real data as to their performance.

In the belief that data of this nature will prove of interest, the writer has chosen a number of the larger sized electric furnace installations, and has set forth rather complete information as to their operation. While the tests thus far are by no means complete, the results obtained have demonstrated that the overall cost of heating electrically compares favorably with other methods.

The element of quality has been more fully demonstrated by the operation of large furnaces, and at the same time other superior features have been brought to light, which in many cases have proven to be of equal or more importance from a commercial standpoint.

The data presented covers such items as labor charges, working conditions, maintenance of equipment, oxidation and distortion of product, cost of subsequent operations, and continuity of service.

A. E. WHITE, University of Michigan; and J. S. VANNICK, Bureau of Standards. Paper: *"Note on Occurrence of Oxides and Nitrides in Boiler Tube Steel."*

Abstract: 1. The presence of compounds of oxygen and nitrogen in specimens of boiler tubing which had been found to be comparatively brittle is thoroughly described. The possible sources of contamination of the metal by the gases and their compounds are cited. A microscopic examination showed that the gases had been absorbed by the liquid metal, in the refining processes. In view of the recent interest in the appearance of nitrogen compounds occurring in iron and steel, the types of structures are described in detail. Attention is drawn to the occurrence of nitrogen compounds of the "divorced" type and a special form of one of them is described in detail. From an examination of the course of cracks tributary to the fractured surface, the path of rupture is found to prefer a transcrystalline course. This course is independent of the oxide streaks or nitride plates thus suggesting that the crystals are inherently brittle, probable due to the presence of gas in solid solution.

2. The relation of the physico-chemical problem of the solution of gases in metals and the practical forms in which the

problem appears are briefly sketched. In view of the lack of a working relation between the chemistry of the gas-metal systems and the corresponding mechanical properties, the quantity of the gases or their compounds that may be allowed in a metal is not definitely known. It is concluded that the miscroscopically visible presence of compounds of the gases in the steel indicate the destruction of its normal properties.

F. H. HELRIGEL, Metallurgist, Motor Products Co., Detroit, Mich. Paper: *"The Heat Treament of Copper and Brass."*

Abstract: The heat treatment of copper and brass, like the training of a child, begins before it is born. There are certain elements introduced into the metals from the ores which no amount of commercial refining will eliminate and which almost entirely govern the quality and use to which the metals can be put.

Copper occurs as pure metal, and as sulphide or carbonate. It is first roasted and then reduced to metal, much as iron is reduced in the blast furnace and later converted to steel in the open hearth. Very few impurities are present in copper. Zinc occurs as sulphide and carbonate and is reduced by distillation. It is from zinc that most of the impurities of brass are obtained; bismuth, arsenic, cadmium, iron, lead and tin occurring most often.

Brass is manufactured by melting up copper in crucibles or furnaces, adding to it scrap brass and zinc and pouring, either into castings or into forms for further working. Every quality that a brass casting must possess is imparted to it by its chemical composition. It can not be heat treated. Brass that is to be used for sheets, strips, tubing, etc., is further rolled, annealed, pickled and the process repeated until reduced to size.

One might state as final and conclusive that there is no such thing as heat treatment of copper and brass, that it can only be annealed, and if the metals were pure and annealing conditions ideal that would be so. However, foreign elements in brass, intentional or otherwise, almost govern its treatment. Iron and lead are to brass what phosphorus and sulphur are to steel, as to machining qualities, hardness and tensile strength. Manganese plays much the same role in each. Brass annealed dead soft, containing tin or iron, has a much higher tensile strength and hardness than pure brass. Other factors governing the annealing are degree of hardness, due to cold working, time and temperature. While the annealing of brass is a simple straightforward proposition, it requires a sympathetic understanding of what ails the metal to treat it accordingly.

J. A. GANN, Metallurgist, Dow Chemical Co., Midland, Mich. Paper: *"Dowmetal and Its Application."*

Abstract: When the United States magnesium industry sprang into existence during the early part of the war, The Dow Chemical Company was one of the parties actively interested. Pure magnesium may have its physical properties materially altered by proper alloying, yielding a series of alloys commercially known as Dowmetal. Its extreme lightness, great strength and other properties peculiar to the metal suggested its use as a piston material. Of all the simpler alloys investigated, the magnesium-aluminum series proved to be the best for piston purposes and, inasmuch as they indicate the general range of adaptability of Dowmetal and at the same time present some very interesting heat treating phenomena, they will be considered more in detail.

The curves presented show the variation in physical properties of magnesium-aluminum alloys with increasing aluminum content. They clearly indicate that alloys of widely different properties are

readily obtained and that for many purposes, the best combinations of physical properties are obtained with six to twelve per cent aluminum. The reason for all this becomes apparent as soon as we study the microstructure of the metal.

Magnesium-aluminum alloys are susceptible to heat treatment, the relative effect on their physical properties depending on the per cent aluminum present. The accompanying microscopic changes again offer us an explanation for the increase in strength.

H. L. HESS, Metallurgist, 216 Wayne Ave., Lansdowne, Pa. Paper: *"Non-ferrous Forgings."*

Abstract: The historical development of copper and its alloys is briefly developed.

Modern methods of melting copper alloys are considered and some space is given to composition.

Attention is then given to one of the most recently developed fields in nonferrous metallurgy namely nonferrous forgings. The machinery used in the production of nonferrous forgings and the possibilities of the finished products are fully discussed.

S. L. HOYT & G. H. BIERMAN, Met. Engrs., National Lamp Works, Nela Park, Cleveland, Ohio. Paper: *"On the Theory of Hardening Steel."*

Abstract: Realizing the present unsettled state of opinion on the hardening phenomena of steel, the authors have gathered together considerable laboratory data in an attempt to crystallize some of these ideas.

The iron-carbon diagram is used as a basis of discussion and heating and cooling curves are taken up.

The work of Portevin and Garvin on "The Experimental Investigation of the Rate of Cooling on the Hardening of Carbon Steels" is used as a basis for the development of several new ideas on microconstituents.

The various modern theories of hardening are reviewed and a "Modified Solid Solution Theory" is proposed.

PROF. O. E. HARDER, Instr. Metallurgy, School of Mines, University of Minnesota. Paper: *"Discussion of the Hardening of Steel and Other Alloys."*

Abstract: Discussion of the Hardening of Steel and Other Alloys—The phenomena observed in the heating, cooling, and tempering of steel are discussed, and especial emphasis is placed upon the important part played by solution and precipitation. Similar processes in nonferrous alloys are also discussed. Some generalizations are made with reference to the heat treatment of alloys and to the future possibilities from researches along these lines.

DON. H. STACKS, Con. Met. Engr., 1558 Boulevard, West Hartford, Conn. Paper: *"The Development of the Grinding Sparks of Steel as a Means of Carbon Determination."*

Abstract: The quality of iron and steel to produce sparks under certain conditions is acknowledged as ancient history.

When a piece of iron or steel is pressed against a fast revolving grinding wheel, minute particles of metal are removed and thrown into space which are observed at lines of fire and which seem to become molten and finally disappear—in case of an almost carbonless iron—shaped like a steel needle with the point in the direction of flight and slightly tipped at the end on account of the rapid cooling effect of the atmosphere. In case the iron contains a small amount of carbon the needle like effect is broken up with

an explosion and little lines of fire dart out of what was originally the needle like body. As the carbon increases, these secondary lines of fire again explode causing further subdivisions and the action continues as the carbon increases, until all that can be observed is a mass of explosions.

When steels contain alloys, such as nickle, chromium, vanadium, manganese, etc., the lines of fire and the spark explosions are more or less interrupted with less line of fire and smaller as well as larger explosions.

When all conditions are standardized, and by the use of known standards and with the personal equation eliminated, the inspection of steel can be successfully carried out by placing the unknown composition along with the known upon a specially designed automatic machine which will throw out two lines of fire and spark explosions simultaneously in such a manner that the carbon content of the unknown will be plainly observed for any commercial specification of steel commercially accurate.

Figures 4, 5, 6 and 7, which represent over one hundred determinations of open-hearth furnace checks and factory control work show that the average spark carbon results are identical with the combustion carbon, with the individual determinations checking on the average within 0.025 plus or minus and with but two extremes of 0.04 and 0.05 per cent of carbon variation from the standard combustion results.

A CONTRIBUTION TO THE PROBLEM OF THE INFLUENCE OF MASS IN HEAT TREATMENT

By E. J. Janitzky

THAT the mass of a piece of steel which has been heat treated greatly influences the physical properties of the steel, is well known, but very little has been done to ascertain whether the law which the relation of the mass has to the physical properties can be determined mathematically. With this idea in mind the author has prepared the following paper, the object of which is to point out that such a law exists, and that it can be determined mathematically.

In the *Journal* of the American Steel Treaters Society, Volume I, No. 1, October, 1918, the author wrote an article under the heading, "Mathematic Discussion of the Influence of Mass on Heat Treating." In this discussion it was pointed out that for a given mass of steel, the physical properties obtained are functions of the surface of the metal quenched. There were computed three different curves, representing three bodies, spheres, rounds, and plates. In these curves the ordinates in each case represented surfaces per pound of steel and the abscissae diameters of the spheres, diameters of the rounds, and thicknesses of the plates respectively.

If the surfaces in square inches per pound of steel be called S, and the diameters or thicknesses in inches be called D, it was found that

$$S \times D = 7.062 \text{ for plates,}$$
$$S \times D = 14.125 \text{ for rounds,}$$
$$S \times D = 21.185 \text{ for spheres.}$$

It will be noted that the constants of each equation are in the ratio 1:2:3. It is obvious that the equation $S \times D = C$ represents a hyperbola in which the asymptotes are rectangular. This fact led to the assumption that the tensile and hardness properties decrease with increased sections, following a hyperbolic curve.

Not having any actual data at hand at that time, it was decided to search for some which would define somewhat closer than heretofore the mathematical relationships which exist in regard to this question. In October, 1920, the report of the British Engineering Standards Association was published and it was in this report, No. 75, that the writer found some very reliable data which afforded an excellent opportunity for this study.

The analysis of one of the steels tested in the British investigation was as follows: Carbon 0.45; manganese 0.78; sulphur 0.02; phosphorus 0.025; silicon 0.32; nickel 0.0; chromium 0.0; tungsten 0.0; and vanadium 0.0 per cent.

The following test results were obtained from bars of this steel rolled to 3¼, 2⅜, 1¼ and ⅞-inch diameter respectively, and machined to 3, 2⅛, 1⅛, and 11/16 inches diameter respectively. The tests were heat treated before machining to test piece dimensions. The figures given in Table I and used in this discussion are considered by the British Committee as representing the true physical properties of the steel after the specified heat treatment had been carried out.

A note here as to the reliability of the results of the British investigators is not out of place. In this work four investigators were concerned, one of

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A paper presented at the Indianapolis convention. The author, E. J. Janitzky, is metallurgical engineer, Illinois Steel Co., South Chicago, Ill.

whom was the manufacturer of the steel; each checked his results in triplicate. The results of the investigators agree very closely on this steel and therefore are considered as representing within experimental error the true properties of metal of this analysis. It should be kept in mind that the results of these tests represent the physical qualities of the center portions of

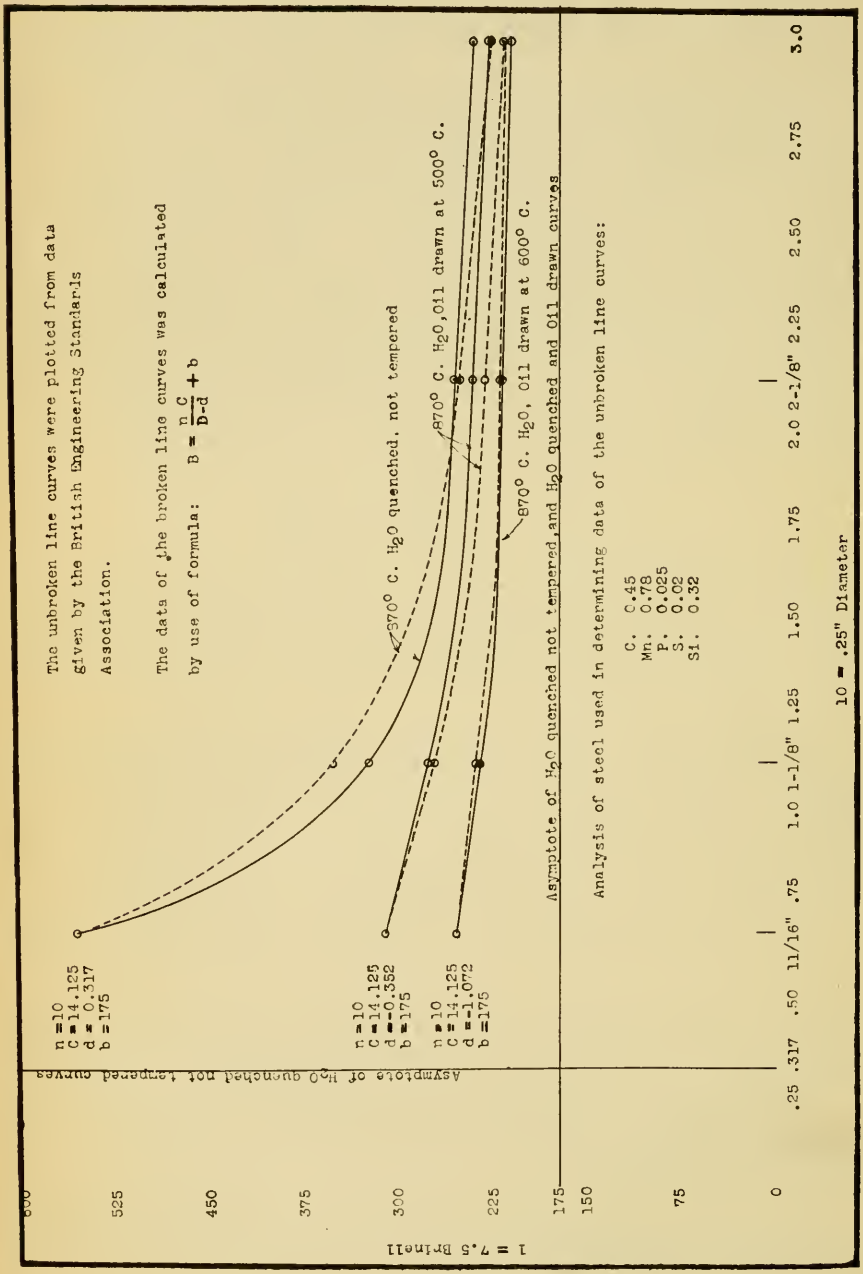

FIG. 1—HARDNESS CURVES OF THE STEEL QUENCHED IN WATER AND NOT TEMPERED AND QUENCHED IN WATER AND TEMPERED

the rounds and thereby avoid any harmful effects which could be ascribed to the steep gradient of the hardness penetration which exists near the surface.

The rolled bars were cut to standard lengths for tensile and Izod tests, the length of the tensile test bar being 6 inches and that of the Izod 8¼ inches. In the case of the 1-inch and ⅞-inch round rolled bars, the tensile test pieces were cut 9 inches long, in order to afford a better grip for the testing machine; in cases where very great hardness was expected after heat treatment, the tensile pieces of the larger diameters were cut 10 inches long. After being cut, all the test bars were centered in an automatic centering machine in order to get the test pieces machined truly parallel with the cores of the test bars.

Table I

Tests On Bars of Varying Mass

Water Quenched from 870 Degrees Cent. and Not Tempered

Diameter of section treated inches	Maximum Stress pounds per square inch	Yield Point pounds per square inch	Elongation per cent	Reduction of area per cent	Izod impact	Brinell
11/16	269,000	258,000	3	4	3	555
1⅛	150,000	95,000	12	28	14	321
2⅛	125,000	83,000	18	43	16	255
3	116,000	76,000	23	54	24	241

Oil Quenched from 870 degrees Cent. and Not Tempered

Diameter of section treated inches	Maximum Stress pounds per square inch	Yield Point pounds per square inch	Elongation per cent	Reduction of area per cent	Izod impact	Brinell
11/16	130,000	96,000	18	50	22	255
1⅛	125,000	83,000	20	49	27	241
2⅛	116,000	76,000	23	54	24	228
3	110,000	72,000	23	55	26	217

Brinell impressions on the fractured tensile tests were made upon flat surfaces produced by milling down the shoulder on a screwed end of each specimen to the level of the cylindrical test portion. Only Brinell numbers of the tensile test pieces are given in this discussion, as they represent the actual hardnesses of the centers of the test pieces and are geometrically identical.

Using Brinell numbers as ordinates and diameters of the quenched sections as abscissae, two sets of curves were plotted from the British figures as shown in Figs. 1 and 2; in Fig. 1 are shown three curves representing respectively, the steel quenched in water and not tempered, the steel quenched in water and tempered at 500 degrees Cent., and the steel quenched in water and tempered at 600 degrees Cent.; likewise Fig. 2 shows curves of the steel treated as above except that the quenching was done in oil.

Consider the general formula, $S \times D = C$, that is, that the diameter of the section in inches multiplied by the surface in square inches per pound of steel for that section is constant. For rounds this formula is

$$(1) \quad S \times D = 14.125$$

The Brinell hardness of any section is in direct ratio to the surface per pound of steel according to the formula

$$(2) \quad B = n \times S, \text{ or } S = \frac{B}{n}$$

n being a factor which is constant for each steel of a particular analysis.

Substituting equation (2) in (1),

$$(3)\quad B \times D = 14.125\ n$$

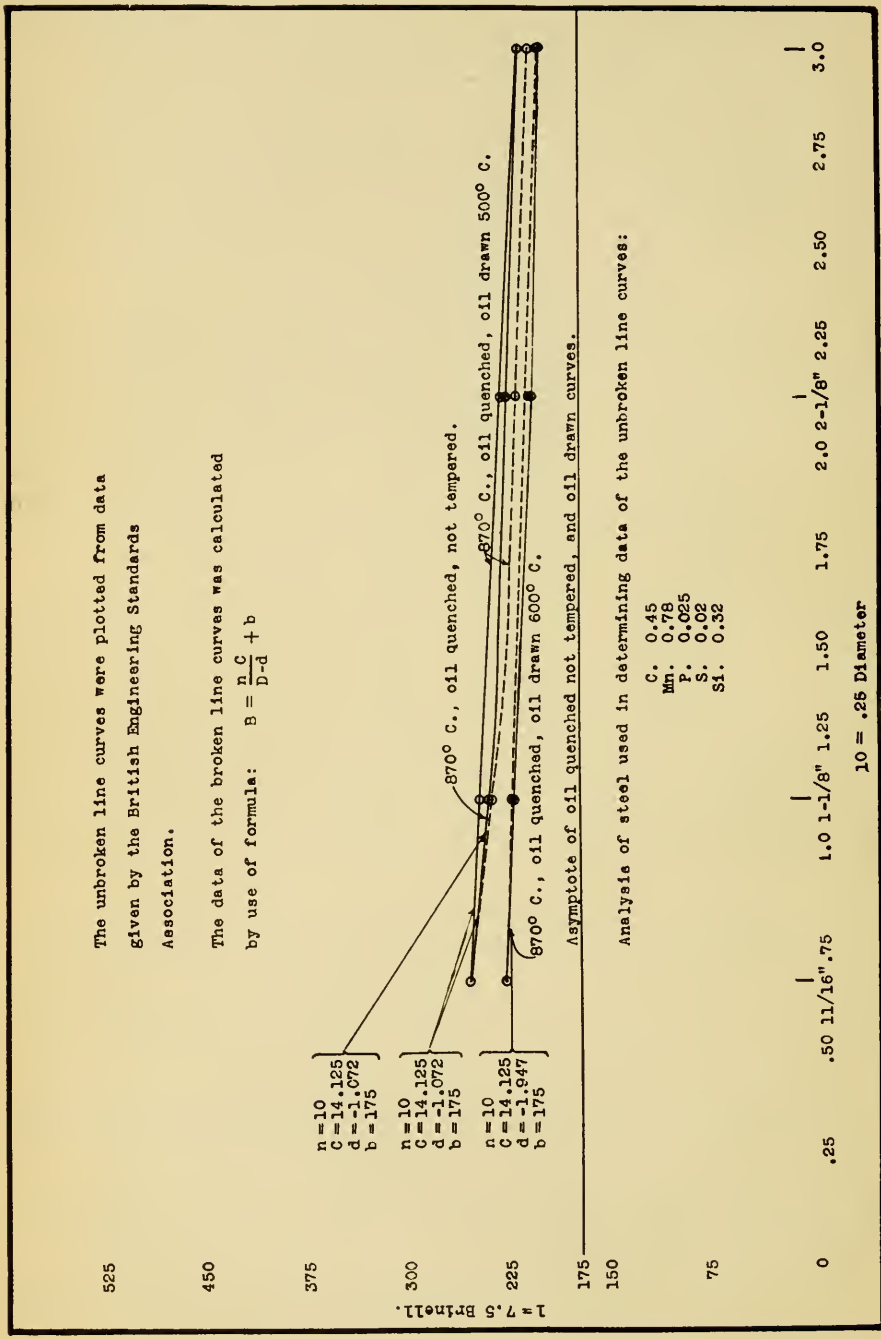

FIG. 2—HARDNESS CURVES OF THE STEEL QUENCHED IN OIL AND NOT TEMPERED AND QUENCHED IN OIL AND TEMPERED

This last equation is a true one, but in its present form is unsuitable for our purpose, inasmuch as it does not take into consideration the asymptotes of the curves. It can be seen that the axes of the rectangular system of co-ordinates are not the asymptotes of the curves. Equation (3) changed to take into account the asymptotes reads

$$(B - b) \times (D - d) = 14.125\ n$$

from which (4)

$$B = \frac{14.125\ n}{(D - d)} + b$$

B is the Brinell hardness of any section desired.

n is a factor which is constant for each steel of a particular analysis; it appears to be the square of the hardening capacity.

D is the diameter in inches of a section the hardness of which is desired.

d corresponds to the vertical asymptote of the hyperbola. By solving the above equation (4) for d, an equation is obtained in which all the factors on the right-hand side are known or can be determined by experiment.

b represents the horizontal asymptote. For this steel it corresponds to a Brinell hardness of 175.

It has been stated that n appears to be the square of the hardening capacity for this steel. The hardening capacity of a steel is the ratio of the maximum hardness which can be developed in that steel to the hardness in the normally cooled state. In this case, the maximum hardness of this steel was taken to be that of an 11/16-inch section quenched in water, which gave a Brinell hardness of 555. Thus the ratio is 555/175 or 3.17. $(3.17)^2 = 10$. Therefore for 0.45 per cent carbon steel, $n = 10$.

Now again consider equation (4),

$$B = \frac{14.125\ n}{(D - d)} + b \qquad (5)\quad d = D - \frac{14.125\ n}{(B - b)}$$

With the discussion as it now stands, the following six curves are considered individually and their equations developed.

(1) 0.45 *per cent carbon steel quenched in water at* 870 *degrees Cent. and not tempered.* From the British experiment, an 11/16-inch round section of this steel quenched in water at 870 degrees Cent. and not tempered had a Brinell hardness of 555. Therefore, substituting in equation (5), using the value 555 for B, and 11/16 for D, there is obtained for d, the vertical asymptote, the value 0.317. Thus the formula for this curve is

$$B = \frac{(14.125) \times (10)}{(D - 0.317)} + 175$$

Using this formula to obtain the values for the Brinell hardness of other sections quenched in water at 870 degrees Cent., and not tempered, the following results are obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	555	555
1⅛	321	350
2⅛	255	253
3	241	228

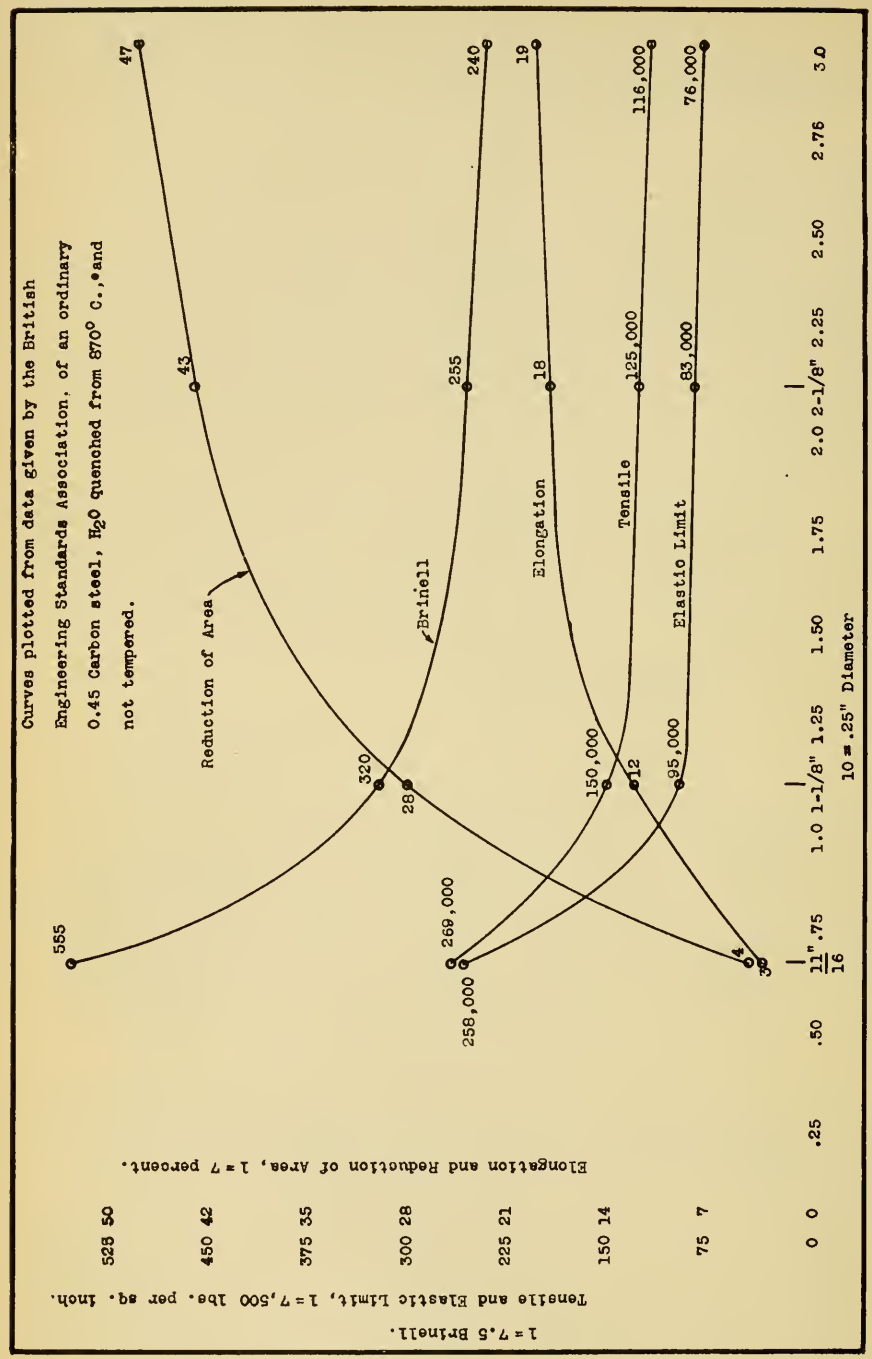

FIG. 3—CURVES COMPARING HARDNESS OF THE STEEL WITH OTHER PHYSICAL PROPERTIES

(2) 0.45 *per cent carbon steel quenched in water at* 870 *degrees Cent. and tempered at* 500 *degrees Cent.*

From the British experiment, B is 311 and D is 11/16. Substituting these values in equation (5), $d = -0.352$. Therefore, the formula for this steel quenched as indicated and drawn at 500 degrees Cent. is

$$B = \frac{(14.125) \times (10)}{D - (-0.352)} + 175.$$

The following results were obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	311	311
1⅛	277	271
2⅛	241	232
3	229	217

(3) 0.45 *per cent carbon steel quenched in water at* 870 *degrees Cent. and tempered at* 600 *degrees Cent.*

From the British experiment, B is 255 and D is 11/16. Substituting in (5), $d = -1.072$. Therefore, the formula for this steel quenched as indicated and drawn at 600 degrees Cent. is

$$B = \frac{(14.125) \times (10)}{D - (-1.072)} + 175.$$

The following results were obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	255	255
1⅛	235	239
2⅛	217	219
3	212	210

(4) 0.45 *per cent carbon steel quenched in oil at* 870 *degrees Cent. and not tempered.*

From the British experiment, B is 255 and D is 11/16. Substituting in (5), $d = -1.072$. Therefore, the formula for this steel quenched in oil as indicated and not tempered is

$$B = \frac{(14.125) \times (10)}{D - (-1.072)} + 175.$$

The following results were obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	255	255
1⅛	241	239
2⅛	228	219
3	217	210

(5) 0.45 *per cent carbon steel quenched in oil at* 870 *degrees Cent. and tempered at* 500 *degrees Cent.*

From the British figures, B is 255 and D is 11/16. Substituting in equation (5), $d = -1.072$. The formula for this steel quenched in oil as indicated and drawn at 500 degrees Cent. is

$$B = \frac{(14.125) \times (10)}{D - (-1.072)} + 175.$$

The following results were obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	255	255
1⅛	248	239
2⅛	228	219
3	217	210

(6) 0.45 *per cent carbon steel quenched in oil at* 870 *degrees Cent. and drawn at* 600 *degrees Cent.*

From the British figures, B is 229 and D is 11/16. Substituting in (5), $d = -1.947$. The formula for this steel is

$$B = \frac{(14.125) \times (10)}{D - (-1.947)} + 175.$$

The following results were obtained:

Diameter of section quenched inches	Brinell Hardness from British Report	Brinell Hardness computed by formula
11/16	229	229
1⅛	223	221
2⅛	207	210
3	202	204

From the foregoing calculations it is apparent that the factors which control d in any carbon steel are the drasticity of the quenching medium and the extent of the tempering operation. As the drasticity of the quench becomes less and as the degree of the tempering becomes greater, the vertical asymptote d moves towards the left into the second quadrant of the system of co-ordinates.

It is interesting to compare the Brinell curve with the curves of other physical properties, such as, tensile strength, elastic limit, elongation and reduction of area. This has been done Fig. 3 shows a similar hyperbolic tendency of these curves. The Brinell and tensile curves run parallel as is to be expected.

The figures given in this paper speak for themselves, and point to the possibility of mathematically predicting results which are to be expected in different sizes of heat treated steel.

EFFICIENCY OF VARIOUS QUENCHING MEDIUMS WITH THEIR PRACTICE AND APPLICATIONS

By James B. Morey

PROPER handling of quenching mediums is one of the most important factors in the successful hardening and tempering of steels. Much has been published concerning various processes of hardening and tempering as well as the furnaces used, but very little has been written regarding the baths or mediums used. In the past, the hardener carefully guarded his own secret composition of quenching baths, however, that time has gone. It is now realized that the mediums must be thoroughly understood and properly handled to bring the desired results of economy and efficiency in the present day production of treated tools.

A first and fundamental consideration is that hardening consists of but two operations of change in temperature; heating and cooling. The object of heating is first, to obtain refinement of structure; and second, to secure the formation of so-called hard constituents in the steel. With this object accomplished, the steel is held in this condition by more or less rapid cooling, depending upon the specifications desired. Water, oil, and air are the most common mediums for such cooling, but many others which are used more or less commercially will be discussed as well.

Regardless of the composition of a quenching bath, the temperature of the bath must be kept uniform at all times in order that dependable results shall be obtained. This is necessary so that successive pieces or tools will undergo the same changes and the results will be the same. Too much emphasis cannot be placed upon this provision, for without a uniform temperature of bath it is impossible to forecast what results will be obtained. Quenching baths of different compositions produce various hardening results due, of course, to the heat dissipating power of the different baths. This property of withdrawal of heat from the steel depends upon the specific heat of the medium, its viscosity, conductivity, and volatility thus by obtaining a proper combination of these various properties, a bath giving the desired results can be secured.

Steel quenched in brine will be much harder than if quenched in water from the same temperature, since the brine dissipates heat more quickly. Oils are slower in their quenching powers than either water or brine, but have a much more uniform rate of cooling at higher temperatures than the latter. Clear cold water is employed commonly for steels of low carbon content, as well as for simple sections of higher carbon steels without danger of fraction due to the internal strains caused by the more drastic action of the water. It is imperative that water or a brine medium be used where the surface must be glass hard. If the steel is required to have a full heat treatment, that is, quenching and toughening, it is possible to secure about the same hardness by either water or oil quenching, providing a lower drawing temperature is used for the oil quenched piece. The objection to oil quenching and a lower drawing temperature is that this temperature is not so easily discerned by its color. In general, however, oil quenching is more desirable than water quenching, since water cools so rapidly that cracking becomes a

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A paper presented by title at the Philadelphia Convention. The author, James B. Morey, is foreman wire mill annealing department, Atlas Crucible Steel Co., Dunkirk, N .Y.

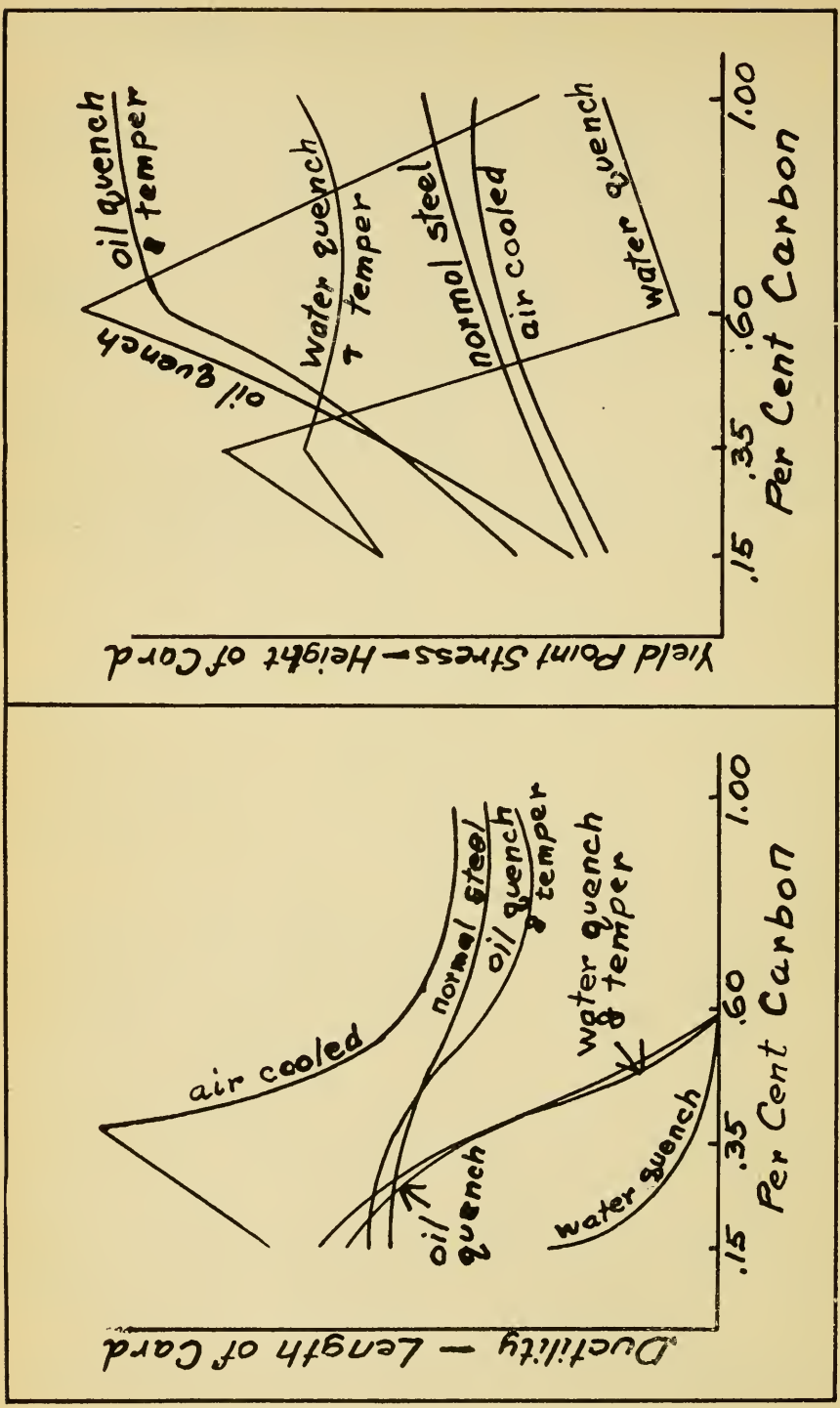

FIG. 1—DUCTILITY OF CARBON STEELS UNDER DIFFERENT HEAT TREATMENTS. FIG. 2—YIELD POINT STRESS OF CARBON STEELS UNDER DIFFERENT HEAT TREATMENTS

serious consideration. If water is to be used care must be taken in its selection, as greasy substances in water sometimes interfere to the extent that the steel cannot be hardened; or if certain acids are present, the steel may become brittle or may even crack.

Sperm and lard oil baths are much used for hardening springs, while raw linseed oil is a good medium for small tools, such as cutters. Brine is little used save for such pieces as require an extremely high degree of hardness, such as files. In this case, it must be certain that the file is of the proper chemical makeup, otherwise cracking is sure to result. Large sections cannot be quenched easily in brine because of the rapid surface cooling while the center remains hot, therefore severe strains are set up and are not relieved during quenching. Cracking is the result. A method of quenching used somewhat on pieces requiring differential hardening, such as die blocks, anvil faces, edge tools, as well as armor plate, consists in spraying the pieces with water under high pressure. This method gives a more rapid cooling than either brine or water baths, but the spray must be of sufficient volume to prevent the formation of steam between the spray and the hot steel.

While discussing oil and water hardening, mention should be made of one or two methods by which tools may be cleaned or brightened at the same time as quenched. A small amount of salammoniac in an oil bath will cause the piece to brighten up; and a solution of 3 per cent sulphuric acid with 97 per cent water will do very well to clean hardened carbon tools. Reamers, drills, and tools of this nature are handled in this manner to obviate the necessity of polishing the flutes after quenching.

Certain special means of applying quenching agents are called into practice on occasion. In the case of large forgings where high tensile strengths are required, it is often considered poor practice to immerse them directly in cold water, thus a bath of oil and water is used, the oil, of course, floating on top and being of the same volume as the water or perhaps a little less. After heating the forgings to the hardening point they are dropped into the oil and then down into the water. In this manner the oil forms a film on the piece which retards the direct cooling action of the water. The time for cooling may be varied as desired by changing the length of time that the piece is held in the oil. In the case of small thin steel tools, this method is used occasionally, with only a thin film of oil on the water. However, this method of oil or water should not be used unless the operator doing the work is thoroughly experienced as cracking occurs easily.

Sea or salt water is the keenest natural water. Water containing soap is sometimes used to form a protective coating around the piece. Sweet milk, mercury and carbonate of lime, wax and tallow are used occasionally for special purposes. Calcium chloride is often added to water, which medium can be used to 175 degrees Fahr. and gives many of the advantages of an oil bath. Air is the common agent used for the hardening of high speed steels, although an oil bath is also employed to a large extent. When air is used, it must be in the form of a blast for mere exposure is usually insufficient to produce hardness.

Regarding the size of tanks for quenching baths, it may be said that they should be of sufficient size to handle the maximum size of stock to be treated, and the number of pieces when operating at capacity should be a consideration. Furthermore, the size should be determined

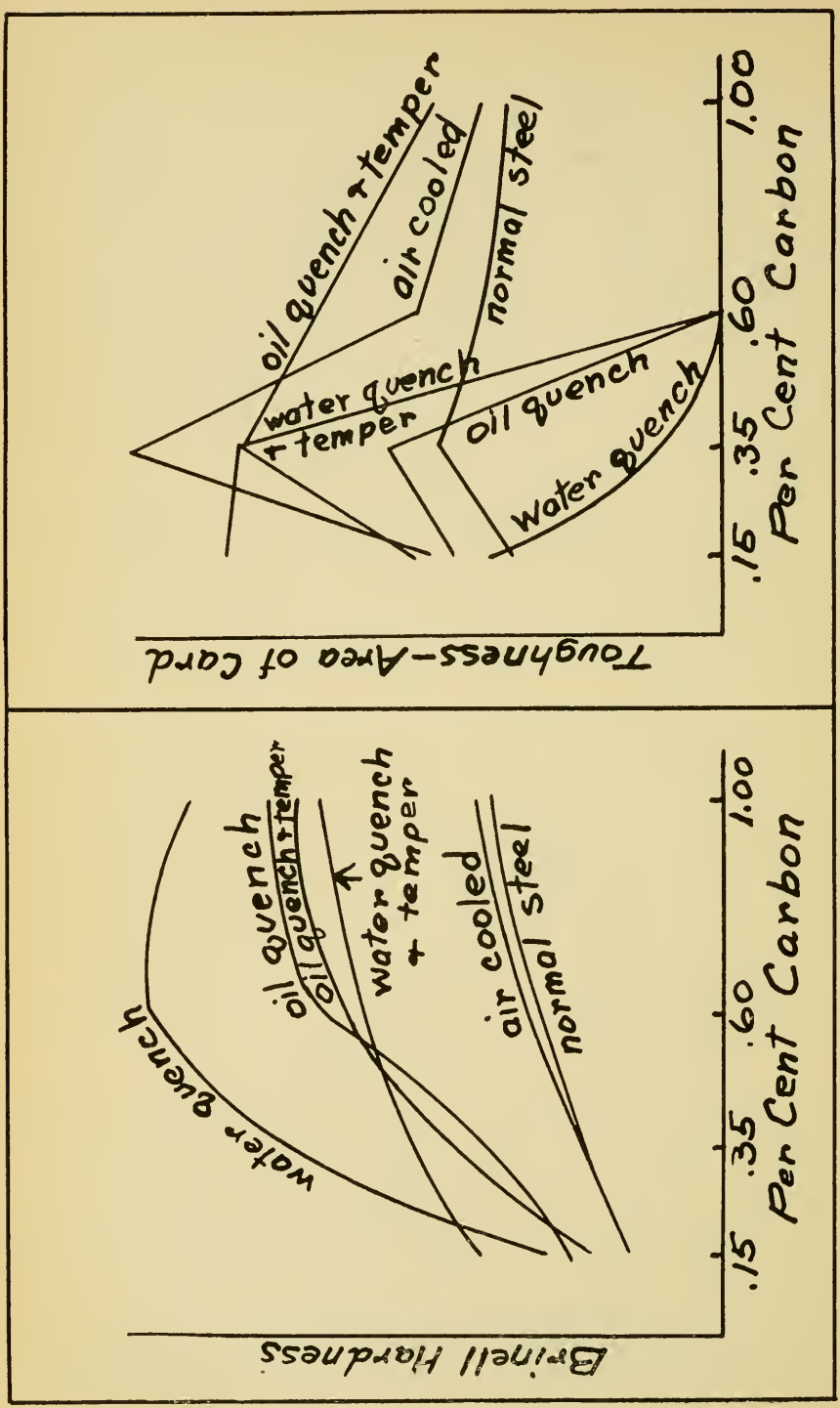

FIG. 3—BRINELL HARDNESS OF CARBON STEELS UNDER DIFFERENT HEAT TREATMENTS. FIG. 4—TOUGHNESS OF CARBON STEELS UNDER DIFFERENT HEAT TREATMENTS

somewhat by the cooling system employed; since the more efficient this is, the smaller the tank need be to operate properly. As mentioned before, the bath should be of uniform temperature at all times, thus it is necessary to provide for the bath being agitated in order that an even distribution of temperature is assured. When the bath is well agitated, the piece being hardened need not be kept in motion. This may seem a minor point, but experience has shown that it is important, especially in the case of long pieces which are more apt to come out straight after hardening.

Best results in quenching are obtained generally when the pieces are immersed vertically in the direction of their greatest dimension, but this rule is not hard and fast. Half-round pieces, plates, axles, etc., require other methods. Irregular shaped tools should enter the bath with their heaviest section foremost. The piece should never be dropped to the bottom of the tank until quite cool. Where one must depend upon unskilled operators, the rule of quenching vertically can be successfully applied in the case of symmetrical sections. To explain why it is best to immerse the piece vertically downward rather than at an angle, let us take the case of a long, narrow round bar. The general tendency is to remove the bar from the furnace with the tongs at the end rather than at the middle, and in the haste to get it into the bath, the average worker will plunge it in at an angle. Thus one end strikes the solution before the rest, and initial hardening strains result which usually cause a bent bar. It is proper to grasp the bar at the end, but care should be taken that it is held vertically as it is plunged into the quenching bath. Especially in the case of hollow forgings such as guns, vertical quenching is essential to prevent the pocketing of any steam that may be formed.

Although much study should be given the proper quenching baths for hardening purposes, it is not nearly so important in the case of tempering baths for the drawing of steel pieces. The object of tempering is merely to reduce brittleness and relieve strains caused by quenching. Oil is widely used where quantity production must be considered. Besides oil, there are sand baths, hot air tempering and tempering in lead, the latter baths being used when the tempering heat must be higher than the flash points of the common oils. The objection to lead baths is that the temperature in all parts of the bath is not the same due to the lead not circulating readily. Initial cost, effects on the finish of tools, and lasting qualities should be the outstanding factors in the selection of tempering baths.

While doing some research work, the author once performed a test to study the properties of several heat treated steels of various carbon contents. It was also desired to make a comparison of their properties after cooling by different mediums; particularly as regards hardness and toughness. The carbon contents of the four steels tested were 0.15, 0.35, 0.60 and 1.00 per cent, respectively. Each steel was given five heat treatments and tested; also a normal steel of corresponding carbon content was tested in order to make a fair comparison with the treated steels. The treatments were as follows: The steels were heated to a high temperature and then air cooled, water quenched, oil quenched, water quenched and tempered, and oil quenched and tempered. The quenching temperature for the 0.15 and 0.35 per cent carbon steels was 895 degrees Cent., and the tempering temperature, 360 degrees Cent. For the 0.60 and the 1.00 per cent carbon steels, the quenching temper-

ature was 800 degrees Cent., while the tempering temperature was 310 degrees Cent.

The test pieces, having received the above treatments, were tested for Brinell hardness, ductility, yield point stress and toughness. The manner of obtaining relative data for the latter three properties was as follows: A piece of steel was placed in the jaws of a testing machine and clamped; motion was transmitted to these jaws by which the piece was bent back and forth, and as the motion progressed a stilus fastened to a reciprocating arm moved up and down on a card, giving a fair representation of the action of the test piece. Thus the length of the card was a measure of the ductility of the piece; the height, a measure of its yield point stress; and the area in hundredths of a square inch showed its relative toughness. The Brinell hardness was determined for each piece by means of the usual method. The accompanying four curves, Figs. 1 to 4, plotted with carbon contents as abscissae and ductility, yield point stress, Brinell hardness and toughness, respectively as ordinates, show the results of these tests.

It seemed that the ductility of the normal steels fell off slowly with an increase in carbon content. The reason for this was assigned to the structure which the carbon caused in the steel and the form in which it was present. In normal steels no carbon is present as an iron carbide, or cementite, a hard, brittle and hence nonductile substance. Thus an increase in carbon in such steels means an increase of cementite and a subsequent decrease in the ductility. As for the pieces that were treated and air cooled, the ductility seemed to be highest for the 0.35 per cent steels and then fell rapidly with an increase in carbon content. The effect of the slow process of air cooling, of course, is the relieving of the stresses caused by previous working of the metal. It would seem that air cooling in these tests was best only in the case of the 0.35 per cent carbon steel, as regards ductility. The water quenched steels lost all ductility above 0.60 per cent carbon. It is probable that this loss of ductility was due more to the rapid cooling than to the increase in carbon content; for it left the steel much in the martensitic stage, martensite being a solid solution of iron carbide in iron, very close grained but brittle and lacking ductility entirely. Oil quenching was not nearly so rapid as with water, as is seen. Here again, however, it is likely that considerable martensite is present after quenching, although the result is not as pronounced as in the case of the water quenched pieces. Also it was noted that when the pieces were oil quenched and then tempered, the ductility for all carbon contents was much improved. This tempering resulted in carrying the piece further toward the sorbitic or softer stage and left little of the martensite, the condition in which the steel would have been had not the piece been tempered. From these results it is concluded that if we had several steels of different tempers or carbon contents and desired but little change in ductility, say from 0.60 to over 1.00 per cent carbon, this treatment of oil quenching and tempering would be preferred.

It was found that in a normal steel the yield point stress increased with the carbon content. This is easily explained by the fact that with increased tempers the iron carbide or cementite present increased; and this substance is decidedly strong, especially in shear. In the water quenched pieces, the higher carbon steels showed a great drop in yield strength, due to the effect of too great cooling strains in this rapid method

of quenching. The oil quenching and tempering seemed to be the best treatment for increasing the yield strength. Tempering relieves cooling strains but leaves some of the steel in the martensitic field or harder condition, while some has changed in some degree into the troostitic or even the sorbitic condition or the softer stages. Hence tempering is a softening process as well as one that increases toughness. The oil quenching and tempering is a good treatment for high carbon steels, as it increases their toughness and relieves their brittleness to some extent.

The determining factor of hardness as a property of steels, is the amount of martensite present. Thus if hardness alone is considered without reference to either ductility or toughness—we would water quench the steel, as this treatment leaves the metal almost entirely in the martensitic field. But this is deleterious to the strength of the piece and may even crack it, so as before, an oil quench and temper treatment is recommended especially for the higher carbon contents. In water quenching and tempering, the tempering caused a decrease in hardness. This treatment is often applied to brittle steels.

In conclusion, an example of heat treatment for a carbon steel is given. In the manufacture of skates, a tough steel that is also hard enough to hold a good edge, is required for the edge or blade. A 0.60 per cent carbon steel, oil quenched and tempered would serve very well for this purpose. Now for the upper part of the skate a tough, strong but not a hard steel is desired. A 0.35 per cent steel, oil quenched and tempered would turn the trick, since it could be shaped and drilled, and is also tough and lasting. A simple process of welding the top to the bottom piece produces a good skate. In the making of carbon tool steels, the carbon range is from 0.80 to 1.00 per cent, and the best practical treatment is one consisting of oil quenching and tempering since this gives hardness and required toughness, with some ductility and good strength.

INVESTIGATION OF FATIGUE OF METALS UNDER STRESS

By H. F. Moore

AT PRESENT, the author is connected with an investigation of the so-called fatigue of metals under stress. So far the more fundamental and simple case of the repeated stress has been studied, without the additional complexity of impact which might bring in other factors. It is felt that this investigation, which has been in active progress for a little over a year, has shown more conclusively than has been shown before that steel under repeated applications of stress, reversed from positive to negative, will not fail below some fairly clearly defined limiting stress that does not bear any definite relation to the ordinary elastic limit in some cases and about one-half the elastic limit in others.

I might be asked, first, what is fatigue. The old view is summed up in the word "crystallization." The idea was that under repeated stress the material changed its crystalline structure. I do not know of any evidence in favor of the theory that metals materially change their crystalline structure under repeated stress. The crystals are broken under repeated stress. The second theory, advanced by Bauschinger, the German scientist, is that under repeated stress some inherent property of the material changes its elastic limit: it is an inherent property of the material, possibly some property of the amorphous cement between the crystals. The third view is that all fatigue of metals is the result of the spread of damage from little localized overstresses.

I do not feel justified in stating my positive belief in the third view as against the second, but I have yet to run across a case of failure of steel or other metal, either in the laboratory or in service, that could not be explained by the gradual spread of damage from some nucleus.

It was found, for example, that it is possible to subject a homogeneous steel, such as a 0.90 per cent carbon steel, that has been thoroughly annealed, to one hundred million reversals of stress as high as the elastic limit of the steel with no sign of failure. The test was stopped at one hundred million because the machines were required for other work. Forty-five days, continuous running at 1500 revolutions a minute is required to produce one hundred million repetitions. On the other hand, a complex structured steel like a chrome-nickel steel that has been hardened with very little drawing, will fail at a stress about 58 per cent of its elastic limit. Between these two are obtained a variety of results.

In the steel work of any building, there are undoubtedly many thousands of places where structural damage was done—where riveted members were bent into place cold and where the rivets were fitted with drift pins, and things of that kind. Locally the steel in the building was stressed beyond its yield point in many places. These little localized overstresses do no damage at all; the building is entirely safe. But if this building were subjected eight or ten times a day to a mild earthquake, these little localized overstresses might be nuclei from which damage would spread and eventually we would have trouble. That is, these little localized overstresses may not be important if the structure is loaded a few times, but they may be of importance if the structure is loaded many thousands of times.

The existence of localized stress has been demonstrated by direct ex-

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A paper presented before the New York meeting of the American Institute of Mining and Metallurgical Engineers, February, 1921. The author, H. F. Moore, is professor of engineering materials, University of Illinois, Champaign, Ill.

perimentation with delicate extensometers by the elaborate investigations of the British scientist, Coker. Localized stresses four, five and six times those that we would get by the ordinary laws of mechanics exist in most of our structures. These stresses, ordinarily, under steady load do no damage but if they are repeated many times may start progressive failure.

So far no failure has been found that could not be explained by localized high stress, at a niche, a crack, at a point where one heat treatment stopped and another began, or where there was local faulting due to that fact, possibly due to a place where there was local blue brittleness—or any one of a dozen causes. Certainly in the case of drill rods the actual distribution of stress must be different from that which any mathematical analysis could predict. It would seem that the spread of damage from the localized overstresses, so far as we can see now, explains the phenomenon known as fatigue.

HEAT TREATMENT NOT ALWAYS THE CAUSE OF FAILURE

By Charles A. Brooks

IN ONE particular pneumatic rivet die which came to the attention of the author recently, four defects were discovered. The end which the piston plunger struck was not sufficiently crowned, the fillet at the shoulder was entirely too small, machine tool lines were in evidence at this point, and there were sharp shoulders where the spring retainers gripped. These defects were a result of faulty design or ignorance, yet when the set proved inefficient, the difficulty was assigned to an improper temper by the man who used it. But the steel treater was not at fault. In another case of intricately shaped car molding dies, failure was also given as an improper temper. Here the true trouble was a slight difference in the oversize thickness of metal rolled, insufficient space between the male and female die, as well as the failure to reheat the metal after the oxyacetylene weld before continuing the operation. Second heatings at a slow gradual cooling down would have relieved the hard state of the metal. In fact, the metal was as hard after the weld as was the small raised sharp edged ring shaped part of the third step finishing dies. Most steel treaters appreciate the hard condition of 1-16 to ⅛-inch steel plate after oxacetylene welding. Until careful attention was given to a second heating with slow cooling down, difficulty was experienced. This with a closer inspection of gage size of stock to be rolled overcame all trouble with roll die failures.

Punches operating on ship plate up to 1-inch thick gave good service but when extra heavy plate 1⅛ to 1½-inch thick was placed under the punch, trouble arose. This was assigned to faulty heat treating, but examination showed that the greater part of the breakage occurred at a point close to the sharp shoulder where the machine chuck gripped the punch. The punches were annealed and returned to the machine shop to be turned back ⅛-inch, leaving a fillet where the sharp shoulder was before. After this change and the identical heat treatment as before, the punches stood up well on the heavier plate. This proved that the original heat treatment was not in error. In a similar instance of a tool for bellying out large boiler tubes before beading them, design was at fault. This tool, which was of the pneumatic type, was of a cut off cone shape with the bellying end considerably out of proportion to the plunger part that fit into the riveting machine. Each die had a short life and several kegs of broken ones had accumulated. A new shape of tool was suggested and although apparently of an impractical nature, six of them were forged. After months of service, the same six are still being used. A record was kept up to 20,000 tubes processed on one die, this being a sufficient number to prove that the new type was practical and efficient. Faulty design, rather than improper heat treatment was the cause of failure in the first dies.

Changes in design of an offset die used for bucking up rivets also proved beneficial to a previously unsatisfactory tool. The changes consisted of generous fillets and providing a longer taper between the heavy and light body parts of the tool, as well as holding the body end of the tool to as small a diameter as possible to overcome difference in weight resistance.

A paper presented before the Philadelphia Chapter. The author, Charles A. Brooks, is foreman steel treater, Bethlehem Shipbuilding Corp., Ltd., Wilmington, Del.

These modifications overcame practically all trouble and discredited the theory of improper heat treatment. Making the reacting hammer pistons from 16.5 per cent tungsten steel instead of high carbon steel overcame wear and breakage on this type of tool. A more recent change of using a slightly shorter piston of the same weight of the longer carbon steel piston has resulted in a faster stroke and rivets driven quicker. Sticking in the chamber of the machine, such as often occurs with carbon tool steel however tempered or crowned, has been eliminated entirely.

A general rule of the average steel treater seems to be the giving of extreme hardness consistent with no breakage. It is also a common belief that the frequent grinding necessitated in high speed steel is an indication that the tools are too soft. This is not always true. With a high speed tungsten steel, the hardest point possible for production may be obtained together with the necessary hardness, but the cutting edge may not have a satisfactory edge retaining property, thereby requiring frequent grinding. A good tool must not have this latter property. A high speed steel containing 16 or 17 per cent tungsten in its hardest state shows edge crumbling but a lower hardening heat with oil quenching ending at flash and a slow cooling will produce a tool, which although considerably softer, will require less grinding and give longer service. The author recalls one steel salesman, who in demonstrating a good high speed steel, lost the sale because he did not understand the practibility of obtaining a lasting cutting edge along with the highest degree of hardness. Of course, there are various causes for tool failure such as grinding too great a clearance, pressing too hard on a dry wheel and then dipping into water, and taking too heavy a cut in the machine. More care must be used as to the service required from the tool; pneumatic vibration, rigid holding for machine service or punch or shear service. The tools must be designed suited for each service. This is just as essential as the steel used and treatment given. The heat treater, toolroom foreman and superintendent must co-operate closely to this end. Many failures will be offset by making a study of the tool or machine part prior to making the design. Tools may be forged or machined easily but they will not always do the work expected. In following old standards, we are too prone to neglect possible causes of failure other than heat treatment.

Too many failures are laid at the door of the steel treater. Thus it is essential that he state explicitly his views when he knows failures are not the result of heat treatment. For the advancement of science his views must be considered. It is impossible to make tools or machines stand up in service when the mechanical design is in error. To arrive at the source of trouble where tools and machines are manufactured and to produce work of good quality, careful analysis, good judgment and co-operation are absolutely essential.

OBITUARY

H. P. MACDONALD, vice president of Snead & Co., Jersey City, N. J., and a member of the American Society for Steel Treating died at his summer home in New London, Conn., on Aug. 25. Mr. Macdonald was born in Louisville, Ky., on May 19, 1880 but during recent years has made his home in Montclair, N. J. He graduated from the Massachusetts Institute of Technology in 1901 in civil engineering. He entered the employ of Snead & Co., the same year and served successfully as assistant superintendent, general superintendent, chief engineer and vice president. He was a member of the Society of Automotive Engineers, American Society of Civil Engineers, and American Society of Mechanical Engineers.

Among Mr. Macdonald's achievements are a number of inventions including a series relative to the electrical heat treating of ferrous and non-ferrous metals by means of internal resistance. This system was used extensively during the war for the heat treating of steel tubing required for airplane plants of Italy, England and the United States. He also made a series of inventions useful in the automotive industry relating to propeller shafts having flexible fabric joints and the preheating of gasoline by means of electric current.

Members of the Society will be shocked to learn of the death of Mr. Macdonald. It will be recalled that he presented a paper at the Philadelphia Convention describing his electric method of heat treatment of shafting and tubing, the paper later being published in TRANSACTIONS. Mr. Macdonald's illness started in 1917. He was operated on for cancer in 1918 after which he made a partial recovery. He was again operated upon in 1921 but his death followed a few months later.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

CARROLL, Frank L., (A-10), Steel Sales Corp., Chicago, Ill.
CLAYTON, Charles Y., (M-10), Box 248, Rolla, Mo.
GLADHILL, H. E., (M-9), 715 East Ann St., Ann Arbor, Mich.
HOWE. A. C., (M-9), American Locomotive Co., Paterson, N. J.
HUGHES, A. F., (M-9), 1522 East 62nd St., Chicago, Ill.
JONES, D. J., (A-10), 3319 Park Ave., Indianapolis, Ind.
KELLER, M. S., (M-10), 114 S. Wisner St., Jackson, Mich.
LAWRENCE, George L., (A-10), 7709 S. Morgan St., Chicago, Ill.
LUEBKE, Otto, (M-10), 519 Clinton St., Grand Haven, Mich.
MONK, Grant, (M-8), 1177-208 S. LaSalle St., Chicago, Ill.
NIXON, I. L., (M-9), Bausch & Lomb Optical Co., Rochester, N. Y.
PATTERSON, W. L., (S-9), Bausch & Lomb Optical Co., Rochester, N. Y.
RICHTER, C. P., (M-10), 309 W. Main St., Massillon, O.
RUSHMER, H. W., (M-10), Westerville, O.
SCOTT, F. L., (M-10), Hughes Tool Co., Houston, Tex.
SHULTZ, L. E., (A-9), 338 West 4th St., Cincinnati, O.
STACK, Edward, (M-6), 6335 Walnut St., Pittsburgh, Pa.
WHITE, H. A., (M-9), Sparks Withington Co., Jackson, Mich.

CHANGES OF ADDRESS

ALLISON, F. G.—from 162 Meredith Ave. to 500 Clinton St., Milwaukee, Wis.
BARTLETT, L. D.—from Nicholson File Co., Providence, R. I. to 4 Washington St., Warren, R. I
BEEARS, Byron—from 401 N. 10th St.—to 925 Robeson St., Reading, Pa.
BOISSONEAU, A. F.—from 6724 Normal Blvd. to 1001 W. Washington St, Chicago, Ill.
BRESSLER, W. J.—from 7042 Torresdale Ave. to 3032 Tyson St., Philadelphia, Pa.
BRODMERKEL, G. H.—from Rio De Janeiro, S. A. to 611 12th St., Franklin, Pa.
BROWN, R. M.—from Gebhart Co. to 412 Forbes Ave., Dayton, O.
BUXTON, C. B.—from 1320 W. 10th St., Erie, Pa. to American Locomotive Co., Schenectady, N. Y.
CANNON, J. D.—from 1414 Grand Ave to 622½ Fifth Ave., Milwaukee, Wis.
CHAMBERLAIN, G. D.—from Standard Seamless Tube Co., Ambridge Pa. to Box 321, Monessen, Pa.
DAVIS, G. F.—from 2 Hubbard Court, to 206 Broad St., Charleston, W. Va.
FITZGERALD, J. J.—from 231 California Ave. to 254 Connecticut Ave., Detroit, Mich.
GUSTAFSON, R.—from 4621 Fifth Ave., Moline, Ill. to 2827 S. Michigan Ave., Chicago, Ill.
HADLEY, F. V.—from P. O. Box 1872 to 18 Tremont St. Boston, Mass.
HANCOCK, G. M.—from Olean Chemical Co. to Union Charcoal & Chemical Co., Olean, N. Y.
HANSELL, H. V.—from 50 East 42nd St. to Park Row Bldg., New York City.
HERSCH, S.—from Automobile Machine Co. to 1257 E. 134th St., Cleveland, O.
JACKMAN, A.—from 710 W. Lake St., Chicago to Dixon Hotel, Kansas City, Mo.
JOHNSON, A. S.—from 24 William St., New Britain, Conn. to 23 Grant St., Chicopee, Mass.
KELLY, R. C.—from 721 25th St. to 2402 Ninth St., Moline, Ill.
KERR, Charles A. T.—from Diamond Chain & Mfg. Co. to Lafayette Motor Co., Indianapolis, Ind.
KILDUFF, J. W.—from Gray & Davis, Amesbury, Mass. to American Bosch Machine Co., Springfield, Mass.
KIRCHER, W. F.—from 815 Hickory St. to 536 N. 24th St., East St. Louis, Ill.
KISSAN, W. H.—from 1105 Chester Ave. Cleveland, O. to Cyclops Steel Co., 120 Broadway, New York City.
LANGDON, B. F.—from 3701 Forest Park Blvd. to 5610 Eitgel Ave., St. Louis, Mo.
LEECH, John—from International Silver Co. to Holmes & Edwards Silver Co., Bridgeport, Conn.
LEOPOLD, R. P.—from 2834 to 2846 N. Marshall St., Philadelphia, Pa.
MILLER, D.—from 1422 Mulberry St., Rockford, Ill. to 318 Douglas St., San Diego, Cal.
NASH, H. L.—from 183 Benefit St. to 176 Camp St., Providence, R. I.
NORRIS, F.—from 911 Main St. to 802 East St., Three Rivers, Mich.
OLSEN, C. W.—from 41 New Park Ave. to P. O. Box 1175, Hartford, Conn.
PARDEE, H. A.—from Halcomb Steel Co., Syracuse, N. Y. to Park Wks. Crucible Steel Co. of America, Pittsburgh, Pa.
PARKS, R. C.—from 206 Broad St. Charleston, W. Va. to 352 Rhode Island St., Buffalo, N. Y.
PFEIFER, C. B.—from 1594 Pennsylvania Ave. to 3691 E. Jefferson Ave., Detroit, Mich.
PIERCE, Paul—from 2015 Bellefontaine Ave., Indianapolis, Ind. to 1110 Main St., Buffalo, N. Y.
PUSITZ, L.—from 1325 Theodore to 5348 Russel, Detroit, Mich.
PUTNAM, W. S.—from New Salem, Mass. to University of Illinois, Urbana, Ill.
RAU, Edward—from 9402 Ravenwood to 5504 Martindale Ave., Detroit, Mich.
SAULINER, Theodore, from Leeds & Northrup to N. Princeton Ave., Swarthmore, Pa.
SHIPMAN, G. F.—from 404 Thomas St., to Ingersoll Rand Co., Phillipsburg, N. J.
SMITH, S. G.—from 97 Boulevard to 123 Sisson Ave., Hartford, Conn.
SPILSBURY, H. G.—from Metal & Thermit Corp., New York City to Long Island, N. Y.
STANTON, R. F. V.—from 33 Hamilton St. to 207 Hillside Ave., Hartford, Conn.

TAYLOR, James—from 17 Harvard St., Schenectady, N. Y. to 312 Third St., Scotia, N. Y.
WADUND, A. P. R.—from 319 New York Ave. to 30 Fairview St., Hartford, Conn.
WHITE, Ray G.—from B. M. Jones & Co., New York City to Crerar, Adams & Co., 239-259 E. Erie St., Chicago, Ill.
WILLETT, J. A.—from 5308 Larchmont to 3737 Blaine, Detroit, Mich.
WILLSE, C. D.—from 2611 South 16th St. to 1886 N. Taney St., Philadelphia, Pa.

MAIL RETURNED

BUCH, James A., R. F. D. No. 7, Schenectady, N. Y.
CLELAND, Theodore G., Standard Fuel Appliance Co., 1646 Woodward Avenue, Detroit, Mich.
DONOVSKY, Z. D., 556 Norton Ave., Hammond, Ind.
EBNER, F. L., 1922 Freeman's Ave., Easton, Pa.
GILMOUR, M. L., (M-8), 406 Hennepin Ave., Dixon, Ill.
HENLEY, W. A., U. S. N. O. P., S. Charleston, W. Va.
HOLMES, W. M., Edward Valve & Mfg. Co., E. Chicago, Ind.
HURLEY, William B., 2895 West Blvd., Detroit, Mich.
JACOBSEN, O., Duriron Castings Co., Dayton, O.
MARCUSEN, Harold, (M-1), John Deere Plow Co., Moline, Ill.
MARSTERS, L. E., 7 Dowes St., Everett, Mass.
McGOVERN, P. F., Quigley Furnace Spec. Co., New York City.
SEMONS, Frank, Spring Perch Co., Stratford, Conn.
STUBING, A. F., Railway Mechanical Engineer, Woolworth Bldg., New York City.
WARD, W. R., Lyells, Va.

News of the Chapters

LEHIGH VALLEY CHAPTER

BEGINNING with a meeting to be held Oct. 10 and continuing monthly throughout the entire season, with meetings on the second Monday of each month, the Lehigh Valley Chapter will institute a series of practical talks on "The Manufacture and Treatment of Steel." The subject has been divided in four parts, namely, manufacture of steel, forging, heat treating, and laboratory practice. Manufacture of steel will include producing of ingots, forging, rolling, casting, manufacture of tool steel, and general inspection. Forging will embody all kinds of forging such as drop forging, press and simple forging. In heat treating will be considered treating of forgings and castings, carburizing, heating and quenching, tempering, and heat treating or hardening of cutting tools. Laboratory practice will consist of chemistry, physical testing, pyrometry, and microscopic examination. The talks will be given by men from the Chapter who have made their subjects a specialty and men who are thoroughly capable of discussing the subjects in a practical manner. J. E. Halbing, Ingersoll-Rand Co., Phillipsburg, N. J., is chairman of the Chapter and A. P. Spooner, Bethlehem Steel Co., Bethlehem, Pa., is secretary-treasurer.

Commercial Items of Interest

ALL trades and industries have been asked to co-operate in the "Perfect Package Movement" to be inaugurated by the railroads, steamship lines and express companies in the United States and Canada in November, which has been designated as "Perfect Package Month." The purpose of the movement is to stimulate further public interest in good packing of shipments and to enable the carriers to improve the transportation service of the country. During November, an examination of all shipments sent by freight or express, will be conducted, to obtain information as to the best shipping methods carried on by the various trades and industries.

In every city and town, the railroad and express people will form campaign committees, to co-operate with local shippers' associations, in carrying out the plans announced for "Perfect Package Month." "Exception Reports" will be made out for all faulty shipments discovered and these reports will be sent to the shippers' association for tabulation, to ascertain how high a percentage of perfect packages, the shippers of that city have attained.

Comparisons of the records made by the various cities during November will be announced at the conclusion of the drive. The entire working forces of the railroad and express carriers, comprising some 2,000,000 men, will aid in the movement. The railroads, through the American Railway Association, composed of practically all of the rail-

roads in the country, are pushing the campaign, as a means of raising the standard of the service, while the express agents are also preparing to interest shippers in the undertaking.

In an effort to improve and stimulate present day business, the Simonds Mfg. Co., Fitchburg, Mass., has sent out to its customers an interesting letter containing some good suggestions. Portions of the letter are worthy of attention and are as follows:

"For the last 12 months we have been liquidating. We have all been wearing out our old shoes, our old clothes, patching up our tools, reducing our stocks and getting along without purchasing, excepting only just the various essentials absolutely necessary to carry along our much depleted business. We have cut out extravagance in so far as purchasing materials is concerned, but statistics prove that we have added another far greater piece of extravagance to our list than any heretofore indulged in, and that is the extravagance of wasted time. We have reduced our energies more in proportion than we have reduced our expenses, and most of us find ourselves today wastefully waiting and watching for the gold nuggets to come to us. In other words, we have stopped hustling.

"We can get along on very little if we force ourselves to do so, but what do we gain by it? The world needs products and all kinds of products. The best thing for all of us to do is to take our losses and start in to work and build them up again; mark the prices of our goods down and cut the price of labor down, and insist on more hours work from every employe and more active work from all salaried employes. Start booming activity and by the reduction of prices enable those working for a lower wage to procure as much, or nearly as much, as during the war period. We all need to stimulate activity in business. This slothful waiting is going to hurt us all."

The Surface Combustion Co., 366 Gerard avenue, Bronx, New York, announces that early in July British Furnaces, Ltd., Millbank House, 2 Wood street, London, S. W. 1, was organized with an authorized capital of £25,000 for the purpose of manufacturing and selling Surface Combustion Co. apparatus in the British Empire. The principal stockholders are the Bryan-Donkin Co., Ltd., Chesterfield, Eng., machinists and foundries; Duckham & Jones, Ltd., London, engineers and manufacturers, and the Surface Combustion Co., New York. The latter company is now represented in all principal European countries and several large industrial furnace installations already have been made. The Compagnie Generale de Construction de Fours, 32 et 34 Rue de la Grange-aux-Belles, Paris, are the sole licensees and manufacturers for the company's apparatus in France and its colonies, Belgium, Holland, Switzerland, Italy, Spain and Portugal. John H. Bartlett Jr., foreign representative for the Surface Combustion Co., has had charge of this work during the last few years and personally supervised the organizing of the foreign sales and manufacturing departments of the new companies.

According to a recent announcement of the United States Civil Service Commission, an open competitive examination will be conducted for a metallurgical chemical laboratorian on Nov. 2. The duties of the appointee will include physical tests, heat treatment, and metallographic

examination of metals; determination of transformation temperatures; calibration of instruments, such as pyrometers; calculation and plotting of results of tests; making sketches and drawings of apparatus. Details of the examination as well as the places of examination may be secured from the United States Civil Service Commission, Washington.

A late bulletin of the E. J. Codd Co., Baltimore, describes new chain furnace and oven doors which are finding wide application on metallurgical, glass and chemical furnaces. These screens consist of a multitude of individual strands of steel chain, forming a penetrable transparent sheet which does not interfere with the view of the interior of the furnace, the passage of the charge, nor the tools necessary for manipulation of the same, yet keeps the heat in and the cold out of the furnace. Several illustrations describe the pamphlet.

TRANSACTIONS is in receipt of the *Bulletin* of the American Foundrymen's Association, which made its initial appearance with the September issue. Its purpose is to keep members informed on association activities, report committee progress, and furnish abstracts of current foundry literature. It will fill the need for a means of communication between the association and its members in the intervals between conventions. The *Bulletin*, which consists of eight pages, is published at 140 South Dearborn street, Chicago. Welcome and best wishes to the new publication.

Tate-Jones & Co., Inc., Pittsburgh, has distributed to readers of *Metal Heating*, a journal published by that company, reprints of a paper "Furnace Conditions for Proper Treatment of Die Blocks," by Dr. S. Trood of the same company. The paper which was presented at the convention of the American Drop Forge Association, June 24, is reprinted from a recent issue of *Forging and Heat Treating*. The furnace discussed is an automatically controlled oil-fired furnace for annealing and hardening die blocks, this type replacing an electric furnace which was more expensive in first and in operating cost.

The Kinite Co., Milwaukee, is circulating a 24-page illustrated booklet in which an alloy for shear blades, re-drawing tools, blanking dies, draw dies, embossing and forming dies, broaches, etc., is described and illustrated. This alloy, according to the booklet, has great resistance to wear, dense structure and close grain, air-hardening quality, freedom from distortion when hardening, and ability to take high polish. In the booklet many examples in the large increases in number of pieces per dressing of tool are given.

At a recent meeting of representative Michigan manufacturers with the directors of the engineering research department of the University of Michigan, Ann Arbor, Mich., approximately $25,000 was pledged for use in advertising that department. About 50 manufacturers attended the meeting. Since the department was organized nearly a year ago, the laboratories, under the direction of Prof. A. E. White, have been co-operating with the industries of the state in the study of problems which would result in public benefit.

Considerable work has been accomplished already but at the recent meeting it was felt that through lack of advertising funds the results were not being utilized to best advantage.

Announcement is made of the incorporation of the Pennsylvania Pressed Steel Corp. with an authorized capitalization of $1,000,000. The officers are: C. K. Olberg, president; Dr. Walter M. Mitchell, vice president; Thomas Gamon Jr., secretary; and L. P. Warner, treasurer. The company will engage in the manufacture of pressed and stamped sheet steel and metal products, automotive equipment, etc. Its plant is located at Wayne Junction, Philadelphia.

Contract for a 90-kilowatt, 220-volt, 3-phase, 60-cycle continuous electric furnace for heat treating ring gears recently was awarded the George J. Hagan Co., Pittsburgh, by the Dodge Bros. Co., Detroit.

Construction of a new drop forging plant 70 x 300 feet, has been authorized by the Columbus Forge & Iron Co., West First avenue, when contracts for the building were given to the Middle States Construction Co. The building, which will cost approximately $50,000, is needed to care for the increase of the company's business, according to Manager David Singleton. It is also planned to remodel the present buildings, while much new machinery will be installed. The company makes anvils in addition to drop forgings of all kinds.

The Indianapolis Metal Treating Co. has established a plant at South and Meridian streets. The company was organized by Edward Turnquist and Frank Mattson, both of Anderson, Ind. Modern equipment has been installed and more machinery has been ordered. Mr. Turnquist is the president of the company and Mr. Mattson plant manager. These men have had many years' experience in the treatment of high speed and common steels.

F. J. Ryan & Co., Philadelphia, industrial furnace builders, have moved their general and sales offices from the Franklin Trust building, Philadelphia, to the Wesley building, Seventeenth street and the Parkway, Philadelphia.

Bulletin No. 234, "The Continuous Treatment of Metals with Automatic and Semiautomatic Furnaces," is the fourth of a series dealing with fundamentals that influence the quality and cost of heated products. This bulletin illustrates practical application of the principles outlined by the previous bulletins of this series. Bulletin No. 230, "The Production of Heat Treated Products" contained five papers: (1) "Factors Governing Quality and Cost of Heat Treated Products;" (2) "Relation of Temperature Control to Uniformly Heated Product;" (3) Selection of Furnaces;" (4) "Relation of Price of Fuel to Cost of Production;" and (5) "Influence of Furnace Design on Quality and Cost of Product." Bulletin No. 231, "Selection of Fuels," contained five papers: (1) "Factors Governing the Selection of Fuels;" (2) "Comparative Fuel Prices on B.t.u. Basis;" (3) "Comparative Heating Value of Industrial Fuel Gases;" (4) "Composition of Industrial Fuel Gases;" and (5) "Utilization of Fuel Resources." Bulletin No. 232, "The Variety of

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TRANSACTIONS

of the

American Society for Steel Treating

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RESEARCH PLANE MUST BE ELEVATED

IN THIS issue of TRANSACTIONS considerable attention is devoted to the question of research, a subject much discussed at the recent Indianapolis Convention. The various papers which were presented and the discussions that followed brought out most forcibly that the proper kind of research is absolutely essential to the welfare of all industry, for without it the wheels of progress would cease to turn. Research is a broad subject and has many phases but briefly may be divided into two classes, namely, that conducted by private organizations for their own development and that conducted by organizations grouped together for the good of the industry at large. It was around the latter type of research that the greatest attention was centered. An outstanding feature of the discussion was that up to the present time, pure research work has not been made sufficiently remunerative to attract men to that field. Many of those now engaged in that work remain solely for the love of the work. That this condition is not to advantage in the advancement of science is realized, but realized only by the organizations engaged and interested in research. Only by a campaign of education for industry as a whole can this phase of research work be elevated to the proper plane to which it belongs.

MORE NIGHT SCHOOLS ARE ESTABLISHED

AT LEAST two more night schools devoted to heat treating and metallography and sponsored by the American Society for Steel Treating have been announced for the coming winter. One is offered by the Philadelphia Chapter at Temple University and the other is to be conducted by the Worcester Chapter. The former is to be operated similarly to the highly successful school of the Chicago Chapter at Lewis Institute while the latter is arranged upon less formal lines. As demonstrated by the Chicago experiment one year ago, such schools serve a useful need and are well patronized. It is hoped that in the future other chapters of the Society will see their way clear to aid to the upbuilding of the profession by the establishment in their localities of suitable instructional facilities for the training of heat treaters and metallurgists.

Such schools ordinarily are conducted two evenings a week for a period of about 20 weeks, from two to three hours being devoted to each session. Instructors are selected from members of the chapter or selected from the members of instructional staffs of local institutions. Fees are made as low as possible, just being sufficient to cover the cost

JOHN ALEXANDER MATHEWS

of operation. These courses offer exceptional opportunities for young men to become heat treaters and for practical shop men to acquire some of the theory of modern practice without in any way interfering with their daily occupations. Shop men should be anxious to receive the teachings of experienced teachers and thus to rise to higher planes in their vocations.

DR. JOHN A. MATHEWS ELECTED TO HONORARY MEMBERSHIP IN THE SOCIETY

AT THE recent convention in Indianapolis, Dr. John Alexander Mathews, president of the Crucible Steel Co. of America, Pittsburgh, was elected an honorary member of the American Society for Steel Treating. For over 20 years Doctor Mathews has been active in investigations of iron and steel, his first being carried on at the old Sanderson works in connection with the study of permanent magnetism. At that time practically all permanent magnet steel used in this country was imported. He was the first in this country to adopt magnetic testing in conjunction with the manufacture of steel. Tungsten and chrome magnet steels were investigated thoroughly. The result was that in about five years this country stopped the importation of magnet steel and a little later began to export it to several European countries.

Simultaneously Doctor Mathews began the study of magnetic properties of miscellaneous steels and alloy products and made some efforts to correlate magnetic and physical properties as affected by analysis and heat treatment. When during the war, tungsten became so expensive and the need for high speed steel was so great that it was not profitable to make tungsten magnet steel, he was instrumental in introducing a substitute magnet steel almost equal to the former grade. In this connection, he discovered that certain alloy steels are magnetically more permanent when quenched in oil than when quenched in water, even though they are physically softer when oil quenched. This was entirely contrary to all previous ideas of permanent magnetism of steel for it had been generally considered that the hardest physical state afforded the most permanent state as regards magnetism.

It was Doctor Mathews' fortune to investigate vanadium steels at an early date and his first inquiry for ferrovanadium brought a quotation of $75 per pound, the entire supply in the country at that time consisting of about 30 pounds of contained vanadium in the form of ferro and this was in the hands of two importers. His investigations included the effect of vanadium on plain tool steel but its principal value was found in connection with high speed steel. Its introduction into this product doubled and tripled the cutting efficiency of high speed steel then on the market. Other elements have been used in additions to high speed steel but their effect has been slight and has resulted in products of limited and special application. In connection with vanadium steels, Doctor Mathews produced nickel vanadium, chrome vanadium, nickel chrome vanadium alloys and furnished samples of this material to the late Henry Souther who was then metallurgist for the Licensed Automobile Manufacturers Association. These were the first vanadium steels Mr. Souther had ever seen and the results of his tests constituted the first authentic data the automotive field had in regard to vanadium steels. Doctor Mathews' investigations of these steels included shock tests which were then seldom made.

When Doctor Mathews went to the Halcomb Steel Co. in 1908, the original Heroult electric furnace first installed in this country was considered a failure and it was contemplated to abandon it. However, with the co-operation of associates, the furnace was operated successfully for the manufacture of a wide variety of products and established a new standard of quality and value in the production of alloy steels.

Doctor Mathews was born at Washington, Pa., May 20, 1872. After studying in the public schools of this place, he took the B. Sc. degree at Washington and Jefferson College and the degree of M. Sc. at the same college in 1896. He next attended Columbia University where he received the degree of Ph. D. in 1898. In 1899, he attended the Royal School of Mines, London University, London, Eng., where he took up research work under Prof. Sir William Roberts-Austin, K. C. B. His first occupation was as instructor of chemistry at Columbia University. He left the university in 1902 to become metallurgist in charge of experimental work at the Sanderson works of the Crucible Steel Co. of America, and two years later he became assistant manager, remaining there until 1908. In this year he became operating manager of the Halcomb Steel Co., Syracuse, N. Y. Later he became general manager, and in 1915 president of the company and at the same time was made president and general manager of the Syracuse Crucible Steel Co. He was elected a director and first vice president of the Crucible Steel Co. of America and was transferred December, 1919 to Pittsburgh, holding that position until November, 1920 when he was elected president of the company, which position he now holds. In the years 1900, 1905 and 1911, he accepted the honorary appointments of assay commissioner under Presidents McKinley, Roosevelt and Taft.

In recognition of the numerous technical papers and results of investigations which he had published, Doctor Mathews had conferred upon him in 1902 by Washington and Jefferson College the honorary degree of Doctor of Science. He was the first recipient of the Carnegie Gold Medal for Research from the Iron and Steel Institute of Great Britain in 1902. In addition to the American Society for Steel Treating, other technical organizations of which he is a member are: Chemists, and Engineers Clubs of New York City, American Chemical Society, American Society for Testing Materials, Iron and Steel Institute of Great Britain, and the American Electrochemical Society.

COMPANY OMITTED FROM EXHIBITORS' LIST

In preparation of the list of exhibitors at the Indianapolis Convention, Sept. 19-24, omission was made of the name of the Atlas Crucible Steel Co., Dunkirk, N. Y. This company was represented with a booth and a display of crucible tool steel, carbon tool steel and drop forgings. The company was also an exhibitor at the two previous exhibitions of the Society and is a consistent advertiser in TRANSACTIONS.

ASSISTED IN PREPARATION OF PAPER

In the paper "A Contribution to the Problem of the Influence of Mass in Heat Treatment" by E. J. Janitzky, metallurgical engineer, Illinois Steel Co., South Chicago, Ill., and appearing on page 55 of the October issue of TRANSACTIONS, credit should have been given to Harry Blumberg, assistant to Mr. Janitzky who aided in the preparation of the work. Mr. Blumberg is a metallurgist with the Illinois Steel Co.

THE UNIVERSITY AND INDUSTRY

By A. E. White

THE underlying strength of our nation is laid to our sterling belief in and support of our religious institutions and schools. It is our unwavering attachment to these two segments of our civilization that has filled us individually, and our nation as a collective body, with those high ideals which have placed America in the forerank of the countries of this world.

There may be those who claim that our churches are losing strength but such views are held by pessimists rather than optimists for the examination of the facts would indicate the grip which our religious institutions have upon us. With incomplete returns for the year 1916 there were reported 227,487 organizations and 41,926,854 members with an estimated national population of 101,882,479. Further the value of the church property of 197,807 of these organizations that same year was given as $1,676,600,582, with an estimated total national wealth that same year of well over $200,000,000,000. A dissertation on our church strength, however, is not the object of this paper. It has been developed to the extent set forth for the purpose of indicating that it still plays and gives every indication of ever continuing to play, a tremendously important part in our civilization.

Hand in hand with our churches are our school systems. During the past few years these fell into a depression at a time when all industrial activities were riding on the top of the wave of prosperity. The depression was due to two conditions. First, the boards of education, trustees and other similar governing bodies were not able to advance salaries as rapidly as industrial concerns. Those, therefore, that remained true to their trust as teachers were financially at a handicap for the high salaries and wages paid by industry caused the purchasing power of the dollar to shrink greatly. Secondly, many teachers and large numbers of prospective teachers joined the ranks of the industrial worker leaving the teaching profession either undermanned or poorly manned. The day of unattractiveness in the teaching profession is on the wane. Today our boards of education can pick and choose and we are not forced to place the training of our youth in the hands of inexperienced or incompetent teachers.

What education has suffered through the ruthless encroachments of industry during the past five years, the field of research has suffered for the past 25 or more years. The difference in the encroachment in the two fields has been purely a matter of degree. In the one case it was in the nature of a rapid poison and in the other in the nature of a slow poison.

Yet we must not censor industry too severely. Much of the trouble from the educational standpoint has been due to a type of organization not elastic enough to meet new and changing conditions with sufficient promptitude; and the trouble from the research stand point has been due to the maintenance of too close adherence to the classical viewpoint and too little appreciation of the vast industrial strides which this nation is yearly taking and the demands these strides are making on our institutions of higher education for a revised viewpoint on research.

Broadly speaking all will agree that research work should be fundamentally tied up with university activity. This being the case our differences are not on the desirability of research but rather on the conception of its

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A paper presented at the Indianapolis Convention. The author, A. E. White, is director of the Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

function; a conception as to whether we should make an effort to attack those phases of research which will mean greater employment and greater prosperity for the people. There are those who feel that such a conception of research is not in keeping with the best traditions of our schools. They feel that all research whether in the philosophical or in the natural sciences, should be abstract, intangible. They fear the possible corrupting effect of money upon those engaged in research, since they believe that attempts will be made to use research for the selfish benefit of a few. They hold themselves aloof from matters of an industrial character. Their training, their very life work has necessarily kept them out of contact with industry and its needs. Because of their ignorance they insist upon viewing collegiate research in the same light as it was viewed by their grandfathers. They are willing to profit by our material advances but are unwilling that our universities should have their share in furthering these advances.

To whom do we owe the developments in our steam and electric transportations? To whom do we owe the electric light, modern sanitary equipment, the automobile and the many other things which make life easier and more pleasant? Would we replace our modern Pullman or automobile with the leather strung coach, would we return to our oaken bucket in preference to our modern bath room fixtures, do we prefer candles to the electric lights? It is true that college men have had their share in these developments, but—and here is the distinction—not as graduates or as alumni doing their work in close contact with the university, but when in large measure, if not completely, divorced from the university. In general it is true that while college trained men have done much in the development of industry and engineering, the universities have, as institutions, kept somewhat aloof.

Personally, the author has no quarrel with those who believe the university should stick closely to abstract research. He, believes we should encourage in every possible way work of that type, for through it we widen our knowledge, we add to our culture and in the field of natural science we work toward laws which are at the foundations of science.

Time will not be taken in this paper to indicate the need and necessity for research work. It will be assumed that there is complete unanimity on this point. During the war just passed the necessity for research and an appreciation of the fact that we were greatly handicapped because we had not previously given it proper attention, was daily thrust upon us. We were all at such a fever heat, that much of the work undertaken did not result in returns to the extent that might have been expected from the expenditures involved. Our experience should teach us one thing if nothing else, and that is that research work cannot be conducted in such a manner as to result in the greatest service if carried out at a time of great stress.

Possibly we as a nation became too enthusiastic in this matter; particularly was this the case with certain firms for they employed almost any one who made any pretense of having ability in research and placed at the disposal of such persons vast resources. With the depression which started last fall these same firms realized that much of their industrial research under the conditions just set forth had not been productive. In consequence there was a swing of the pendulum in the opposite direction. Possibly it has gone too far. There appears to be today a more sane attitude on this proposition. Persons are sought in this work because of the ability which they are known to possess rather than because of blatant self-advertisements.

Furthermore, there seems to be a growing belief that research should

be handled through associations and groups of interests rather than by individual companies. This feeling possibly is not held in a few of our major corporations, for due to their very size they can carry on research work as advantageously as any group. Nor is it possibly true in the field of certain endeavors which seek for secrecy. Yet most industries appreciate that they have problems which are common to their competitors and that research work carried out under joint alliance would be beneficial to the industry as a whole and to them individually. It is in this latter field of research that our universities have a splendid opportunity to be of service to the industries themselves, to the field of science and to the advancement of the well-being and prosperity of the people as a whole.

In 1916 there were 574 universities, colleges and schools of technology in this country. Roughly speaking we may divide these institutions into two classes, one of which we may speak of as our endowed colleges or universities and the other of which we may speak as our state universities. Of the former there are over 59 which have an endowment of over $1,000,000, there are but ten which have an endowment exceeding $10,000,000, five with an endowment of over $20,000,000, three with an endowment of over $30,000,000 and but one namely, Harvard University, which has a greater endowment, the exact figure being given as $43,000,000. All of these sums are not available for such expenditure as the governing body of any given university may desire, for many of the donations are so presented that the uses for the income are specified. Of this money there is very little available for research work and therefore the method wherby institutions of this type may operate in this field is different than the method or methods under which our state universities may operate.

Schools and colleges supported in part by state or national funds represent a later development than those supported in whole or in part by funds from endowment. The first state university in this country was established at the University of Virginia though the university which has stood as the outstanding state university since its establishment in 1837 is the University of Michigan. This institution, for example, today has a yearly income from its mill tax of approximately $1,000,000, and an income from tuition fees of approximately $1,000,000. The income from the mill tax represents an endowment of 5 per cent of $60,000,000, which sum is in excess of that of any of our endowed universities. Further, the state legislature at its 1921 session granted $4,800,000 for the erection of new buildings and the procurement of increased facilities, with a promise that additional sums would be granted for such further legitimate needs as might develop. The statement of the conditions at the University of Michigan does not necessarily mean that the operating income of the university is in excess of that of some of our larger endowed colleges and universities for in some of these latter schools the gross operating income is made to equal that or exceed than in many of our state universities through higher tuition and matriculation fees. There is every attempt on the part of our state universities, however, to keep these fees as low as possible for it is one of the primary objects and purposes of our state universities to provide higher education at as nominal a cost as possible.

The favorable conditions which exist at the University of Michigan can be or are equaled in many neighboring states. In fact, were the matter of state wealth a criterion of university strength the conditions just set forth as exisiting at the University of Michigan could be surpassed in the states of New York, Pennsylvania, Ohio, and Illinois and would be closely ap-

proached by California, Iowa, Massachusetts, Minnesota, Missouri, New Jersey, Texas and Indiana.

These state universities, because they are in large measure supported by funds from the people, owe to industry and to agriculture a greater responsibility than is the case with our endowed institutions. With the present funds available they cannot enter the field of research to the extent they would like. Additional sums must be procured. There are set forth six plans for this work. Some of these are applicable to our endowed institutions although such is not the case with all of them.

I.—Income from Individual Problems

This plan would require each individual firm or group of interests to pay the larger share of the cost of each piece of work undertaken. This is a procedure which is in operation at Mellon Institute and is fundamentally the procedure under which the Massachusetts Institute of Technology now operates. In both of these institutions, however, special privileges are granted the donors of the funds, such as deferred publication, opportunities to patent and other matters of a similar character.

There are those who feel that state universities should operate under this plan although there is considerable question relative to matters of deferred publication and the granting of patents. It must be appreciated that state universities are the people's universities and no special privileges should be granted which will be unfair to the people of the state or give any interests in the state undue and unfair advantages. Yet, one must also realize that through the acceptance of funds to cover the larger portion of the cost of an investigation the university owes the donors of such funds a certain responsibility in the matter of protection from the inroads of unfair competition. Succinctly stated the question is this, how can the donor of funds for research work be protected from unfair competition and at the same time how can the state universities as the recipient of such funds protect the people?

It is the writer's personal feeling, and in this matter he speaks as a private individual and not as director of the department of engineering research at the University of Michigan, that no patents resulting from the research activity should be granted the donors of funds. It is his belief, however, that patents should be granted and taken out in the name of the university or in the name of some corporation indirectly connected with the university so that the work be protected from fraudulent patenting.

The matter of deferred publication presents, it is believed, quite a different angle. In the first place no publication should be authorized until after the results are checked and thought over sufficiently to procure the minimum possibility of error. It is believed that at least one year should elapse between the time of the completion of the work and its publication. In the meantime the report should be examined by a competent technical committee and with its acceptance of the technical data contained, it should be passed to a committee from the university for approval relative to university policies. Proper survey by these two committees will require well toward a year.

Secondly, the university by the acceptance of funds for investigational purposes is doubly obligated. It must protect and safeguard the people's interests. It must also prevent the use of the information procured by unscrupulous competitors of the donor until such time as the donor is in a position to protect and defend his interests properly. Though it would be im-

proper for a state university to grant exclusive use of information through the protection afforded by a patent, yet the donor should be protected to some degree and the method recommended is the withholding from publication of the data procured until the lapse of one or more years. In the name of the public we must be careful not to step over backwards. If we accept money from a donor we owe him a certain obligation. Further new processes unless protected in some slight measure are not enthusiastically received by the business world. Failure to appreciate the responsibility incurred through the acceptance of a donor's funds because of the denial of deferred publication may result in no research being conducted on a given problem. This same problem, if solved and the results placed at the disposal and use of the people, might redound to their great benefit and service.

Though privately endowed universities may grant special privileges on state universities, if engaged in research for private interests who in large measure pay for the work, should only do so under such conditions that the people's as well as the donor's interests are completely safeguarded.

II.—Income from State

This is a method which is applicable only to our state universities. It is the one employed by the University of Illinois. It has certain advantages in that it insures continuity of income. The main disadvantage is that it does not procure close contact between the university and industry. These latter are only vitally interested when financially concerned. The problems attacked, therefore, though valuable and distinctive, lack that close relation to industrial needs to make them of maximum service. For this reason this method of financing research work is not enthusiastically endorsed.

III.—Formation of Association

The third plan calls for an organization in each state of chambers of manufacturers with annual dues based either upon capitalization or number of employes. This plan is not recommended for there would be no fair division of the service which a research department might render. Certain firms or interests would procure great service, whereas other firms because of the failure on their part to properly present their needs or the failure on the part of the university to appreciate these needs would be neglected. As a matter of fact in the State of Michigan we have close contact with the manufacturers through the Michigan Manufacturers' Association. The contact involves no obligation on the part of either the University of Michigan or the Michigan Manufacturers' Association though because of the contact there is a community of interests and a channel for the interchange of service.

IV.—Joint Financing
Industries Provide the Endowment—State the Building

A further plan applicable only to state universities is the one wherein the industries provide the endowment and the state the building. This arrangement would bring home to the manufacturers their interest in the department because of their contributions and it would lead toward their taking an interest in order to receive some return from the contribution made. It is not whole-heartedly endorsed as it offers no vehicle for providing definite interest on the part of the industries in the given problems on which work is in progress. Attempts in this connection can be made through an agreement to work on only such problems as meet with the approval of such proper committees as may be appointed, but the work leading to the solution

of these problems would be watched by the manufacturers with much more keenness if they were vitally concerned with their financing.

V.—Joint Financing

Industries Provide Buildings—State the Endowment

This method is also applicable only to state universities. It is open to the same criticism as applies to the preceding plan. For this reason, therefore, it will not be developed at further length.

VI.—Industries Provide Building and Endowment

This is a plan open to our endowed universities and to our state universities. It is a plan under which our privately endowed universities could probably operate. As a matter of fact the first plan and this one are probably the only ones under which they can operate. For state universities it is not recommended to the same extent as the first plan, namely, that whereby the state provides building facilities though the cost for each individual problem be borne by the interest or interests requesting the investigation.

At the present writing there are four institutions which have undertaken definite forward steps in engineering research. Mellon Institute at the University of Pittsburgh has been built through private gifts and private interests pay for the researches undertaken. It is operating substantially under the sixth plan. The Massachusetts Institute of Technology operates under a similar arrangement though the building in which the research work is done was not purposely erected for research work so much as it was for instructional work and the funds which have been received by the institute were not paid with the definite understanding that a given problem would be attacked. Rather they were paid by firms with the understanding that they would be privileged to bring such research problems to the institute as they might desire provided they would still further agree to pay the specific costs involved. This plan is substantially the sixth one named though it is set forth along with that of the Mellon Institute because of its slight dissimilarity. At the University of Illinois we have a department of research which is supported exclusively by state funds. This is essentially the second plan that was mentioned. At the University of Michigan we have in process of development a plan whereby the state provides buildings, library facilities and the use of such testing equipments as it has in its various laboratories. The interests requesting the work pay for the services of those engaged and for such special apparatus as may be required.

It is incumbent upon all universities to keep forcefully before the public the facilities which they possess for research. We must also fully appreciate that the further advancement of universities depends in large measure upon the research facilities made available to the staff. Research at our institutions of learning has not advanced in the same degree or in the same proportion as has research in our private industries. If there is any course which will result in the killing of the goose which lays the golden egg this will be the course to follow. Research must be encouraged and research facilities must be made available for our faculties in order that (1) the teachers may be content to remain connected with universities and thus give of themselves and their inspiration to the student body, (2) in order that there may be suitable training schools for the young men who are to go out into the field of research for private interests, and (3) in order that the universities may keep abreast of the times and do their share in the advancement of our civilization.

THE GOVERNMENT LABORATORY AND INDUSTRIAL RESEARCH

By George K. Burgess

MUCH has been written recently concerning the various aspects of industrial research and especially the role that is being played, or should be played, by each of the various types of organization, such as the engineering society, the university, the independent research organization, the government, and industry itself; and the discussion often has centered about the co-operative aspects of research as between two or more of these parties.

It is generally conceded by representatives of industry that industrial research has for its immediate object the increase of profits, and consequently the brunt of the cost of maintenance should be borne by industry, which should also itself carry out at least the greater part of the research work required. There is a very great divergence of appreciation of the need and value of research in the various industries, and the practices and methods also vary greatly. It is also generally conceded that the role of the university is to train men and increase our store of knowledge; many think useful co-operative arrangements in research may be made between the university and industry, and many illustrations are available.

It is not the purpose of this paper to go into a philosophical or academic discussion of what part the goverment laboratory should play on the stage of industrial research but rather, accepting the fact that tendencies as they are, to state briefly what two of the government bureaus are trying to do to encourage and help industry through research in science, engineering and technology.

It has been well said: "All research is in the public interest, and that from the public viewpoint the sole difference between abstract and applied science is one of degree and not of fact; that the important point is increased research activity irrespective of where or by what means it is carried on." If, therefore, the public has an interest in and derives benefit from industrial scientific research, it is both fitting and fair for the public, through the agency of the government laboratories, to both participate in and help support such research.

It also follows that there should be established and maintained the closest relations between the representatives of industry on the one hand and of the government laboratories on the other. This intimate contact evidently should not be limited to scientific and technical staffs of the industrial and government laboratories, but should embrace also the directors of policy in industry and government. There is another and most important characteristic of the government laboratory in its relation to this question of industrial research, one that has been often mentioned, namely the desirability in many cases of having the work done in whole or in part by an impartial body representing the public and on whose results will be impressed the stamp of authority; as in cases in which if one or the other party, as producer and consumer, either alone or together published the results, they would not carry the desired weight, however well executed.

Again, one should not lose sight of the fact that our government is

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A paper presented at the Indianapolis Convention. The author, George K. Burgess, is chief of the Division of Metallurgy, Bureau of Standards, Washington.

the largest business organization in the country, therefore, the most important buyer and also maintains several types of industrial or manufacturing plant of a highly technical nature. So the government itself, in the conduct of its business, is a party vitally interested in the progress of industrial research, economies in buying, and standardization of products. The results obtained in its laboratories on its own problems are freely given to industry. The role of the Bureau of Standards has been pre-eminent in research for the government and many of its activities in the field of industrial research have been started for the purpose of meeting government needs for information relating to improvements in manufacturing processes, standardization and the formulation of specifications. As illustrations, may be cited the investigations relating to cement, concrete, paper, leather, rubber and textiles, for which small manufacturing plants have been installed.

It is often maintained that there are three essential steps in many branches of industrial research, particularly as related to new processes. First, the laboratory investigation; second, the development on a small manufacturing scale; and third, full scale production. All of these require experimentation. The government bureau may be and often is associated with all three of these stages.

What now do we find to be the relation of the government laboratory to the industries of the country? We may perhaps best approach the subject by asking of what aid can the government laboratory be to the American Society for Steel Treating, to its members individually and to the industries it represents? There are two government bureaus the work of which is most nearly related to the scope of interests covered by this Society, namely, the Bureau of Mines, Bureau of Standards. Each of these bureaus is vitally concerned with promoting the welfare of the nation in matters relating to their respective fields. They may be considered as great technical, service bureaus to which the engineering, scientific and technical interests of the country may apply for help in solving many of the underlying problems of general interest in mining, technology, engineering, physical and chemical science, and in standardization, on all of which progress in industry is based.

From the viewpoint of co-operation with industry, how do these two institutions function with respect to industrial research, which we may define as research with an avowed utilitarian motive? Let us consider first the Bureau of Mines. In the annual report of the director for the year ending June 30, 1920, appears this statement:

"During the past few years the bureau has been building up investigative work with outside co-operating agencies in a manner unique among federal bureaus. The detailed agreements entered into differ among themselves, but the fundamentals are these:

"1. Some state, or university, private or semiprivate organization, has problems in mining or metallurgy the solution of which would benefit itself and the public.

"2. These outside agencies agree to pay part or all of the cost, both in personnel and materials, of the investigation, which is to be carried on under the direction of, and according to the methods of the Bureau of Mines.

"3. The Bureau of Mines retains the right to make public and print the results of all such investigations.

"So successful has this method of solving problems been that at

present the bureau has co-operative agreements with state agencies in 11 states, with 12 different universities, and with 19 private and semi-private agencies. And the total amount of money being spent by the outside agencies on these co-operative agreements, mostly under the direction of the bureau, has amounted to approximately half a million dollars during the present fiscal year. In addition, a number of representative concerns in leading mining and metallurgical industries have appropriated money to be spent under the direction of the Bureau of Mines in production of educational motion pictures illustrating various mining and metallurgical industries. The bureau has found that these films are in great demand by the public, and that they have materially assisted the wide dissemination of information concerning the industries."

As in the case of agriculture, the Mining Industry is scattered over a wide geographical area and the problems to be solved are often local; therefore it was but natural for the Bureau of Mines to follow the practice of the Department of Agriculture in establishing experiment stations at suitably located points for the study of problems relating to the mining industry.

The Bureau of Mines is also charged with the government work on fuels—a subject of no little interest to the membership of this Society—which include, of course, coal and petroleum products of widely diversified types and situated in many areas. In its study of fuel problems, the Bureau of Mines has carried on both the field and station type of investigation but has also been able to concentrate in one or more central laboratories much of its fundamental research work.

In problems relating to process metallurgy, such as the recovering of the various metals from their ores, much the same procedure has of necessity been followed as for the mining operations, namely, work at outlying stations. In both mining and metallurgical investigations it is the custom to co-operate on an intimate and intensive scale with existing industrial plants, to the great benefit in the increase of our knowledge and improvement of the processes concerned, to say nothing of the evident economies of such methods of co-operative investigation. With the experience gained by this bureau in successfully overcoming the difficulties in one region available for new problems as they arise elsewhere, there is evidently also elimination of much wasted effort in trying out a new or metallurgical process.

In its investigations relating to mineral technology and elimination of waste in metallurgical operations, this bureau is doing much of direct interest to this Society, such as smoke and fume abatement, health conditions in shops, furnace design and operation, metallurgical refractories, and the making of alloy steels, and many others, the consideration of which here would take us far afield.

Turning now to the Bureau of Standards, we may note certain differences in methods and procedure as compared with the Bureau of Mines. We have seen how the latter bureau maintains a large number of widely scattered units or stations. In contrast to this decentralized practice, the Bureau of Standards has practically all its work concentrated in a group of laboratories at Washington although it has maintained an important station at Pittsburgh mainly for engineering work on structural materials which station, however, is being moved to Wash-

ington. There are also a few small detached stations for cement and chemical testing.

Again, the Bureau of Standards has followed less generally than the Bureau of Mines the practice of entering into formal co-operative agreements with states and other public or private bodies. We have usually adopted the less formal but nevertheless effective practice, in our relations with industry, of orienting and organizing our work through the instrumentality of committees representing industry.

It has been said committees do no work and therefore are unnecessary, but a moment's consideration will show that in many ways a well organized committee is most valuable, if not indispensible, in laying down principles and suggesting policies, resulting from the united experience of all its members. The Bureau of Standards finds in many lines of its work relating to industrial research that the committee method of outlining the problem is the only feasible one. There is established a mutual confidence among all interested parties so essential in attaining the maximum output with minimum risk of misdirected effort.

As a text defining the bureau's relation to industry, let us quote again from A. W. Berresford in his presidential address before the American Institute of Electrical Engineers:

"I conceive it to be the prime duty of the industry, first, to agree on what shall be the scope of the bureau; second, to educate the bureau in its conditions; and third, by demanding that its interests be heeded, to secure the adequate support of the bureau."

At the outset, it may be laid down as axiomatic that the director of the bureau has never considered undertaking any problem in research relating to industry without first consulting representatives of that industry, either as a group through some organized body speaking for the industry or by consulting with men of authority in the industry. Many are the illustrations of this practice; for example, there has been for years a committee appointed by various bodies interested in nonferrous metals, known as the "Committee Advisory to the Bureau of Standards on Nonferrous Metals", or for short, the nonferrous committee, which meets at the bureau twice a year. All the work on this subject is gone over before and during its execution, so that the nonferrous metal investigations of the bureau have not only the endorsement of the industry but the industry itself formulates the program. If progress in this domain has been less rapid and extensive than we should like, may we then say that, although the first two of Mr. Berresford's conditions have been met, the third is lacking?

The work on railroad materials has less formally been largely mapped out as a result of meetings of representative railroad groups held at the bureau. Sometimes a specific problem that appeals to the bureau may be presented by some railroad together with a manufacturer; such was our work on rails from different ingot types, and the investigation now being conducted on titanium treated rails; or again a manufacturer's association as that of chilled iron car wheels may ask the bureau to co-operate in carrying out an investigation on thermal stresses in chilled iron car wheels as related to design and braking; or it may be an unorganized group, as that of the steel wheel manufacturers, asking for and getting a similar investigation. Nor should there be forgotten the bureau's activities in the realm of engineering materials in its relation to the numerous committees of the American Society for Test-

ing Materials, which committees are fairly representative of both the consuming and producing elements of their respective industries and represent as well the engineering public. I suppose the list of direct or implied requests for work by this engineering body alone would reach the size of a substantial volume.

Whether he realizes it or not, every person in this country is vitally concerned in the limitations set for sulphur and phosphorus content in various grades of steel. If these limits are fixed too rigidly the cost of living rises, if too loosely, the life hazard of all of us is increased. This problem was brought formally to the bureau's attention by two bodies, one representing the government, the other the engineering fraternity; or by the United States Railroad Administration and the American Society for Testing Materials. A joint committee was formed representing the government departments, the specification making bodies, and the manufacturers. The testing and research is carried out in the government laboratories at Watertown, Annapolis and Washington, and the steel is specially produced for the investigation by the manufacturers under the oversight of the committee. A unique feature of the conduct of this investigation is that there is not a two sided table with manufacturers on one side and the users on the other—but it is a round table affair with each man responsible for endorsing each stage of the program so that no member can later say, why did you not do this or that?

The bureau's investigations on electrolysis as related to public service companies and cities are being organized on a somewhat different but nevertheless highly satisfactory basis, in which all interested parties are represented and the program put up to the bureau by them.

Hardly a day passes that there is not one, sometimes several, formal or informal conferences at the bureau by groups representative of industry who are interested in having the bureau undertake problems of research fundamental to their industry, and at those conferences the work to be done is usually mapped out, at least on general lines and often in great detail.

At the present time much attention is being given to problems relating to the elimination of industrial wastes. The possibilities of progress in this field are of unlimited extent. In a sense, of course, all industrial research from which beneficial results are obtained lead inevitably to the equivalent of elimination of waste by conservation and better utilization of materials, improved quality of products, recovery of by-products, increased efficiency of performance, or discovery of new processes and products. There are, however, many instances in industry in which the waste, as such, is evident and manifestly preventable, and it is to problems dealing with these classes of waste to which I refer. As examples we may mention the enormous losses caused by corrosion, inefficient furnace operations, excess use of manganese, and other preventable losses of material and energy in steel manufacturing operations.

Another field of industrial research, and one that will grow in importance, relates to our foreign trade, particularly the specification and testing of materials for export. The establishment and maintenance of standards in this wider competitive field will require much more experimental research than might be thought necessary. In fact in the realm of standardization and specifications, as those of you know who may be familiar with some phases of this subject, it is impossible to get far in

writing a specification before you enter the unknown, and the way can be cleared only by further experimental investigation.

We might cite many other types of problem related to industrial research on which the Bureau of Standards is now working or is qualified to assist in solving in collaboration with industry, but the author trusts what has preceded has given you a better idea than you had before of the relation of the bureau to industry and the readiness at all times on its part to participate with industry in the solution of those problems of general interest coming within its scope. The same is, of course, equally true of the Bureau of Mines.

Mention should be made of one other type of activity at the bureau —still in an undeveloped state—which gives promise of being of considerable value to industry. This is the practice started about two years ago of an industry sending men to the bureau to work on problems that industry is interested in having solved and for which the equipment and atmosphere of the bureau may be particularly suited. This practice was instituted by the bureau largely in self-defense at a time when manufacturers were drawing men from the bureau in alarming numbers and it was also coincident with the reduction of the bureau's funds. We call these men research associates or assistants, and at the present time there are twenty, six of whom are working on metallurgical problems, and the others on problems relating to hollow tile, terra cotta, visibility, lime, gypsum, plasticity of fats, cement, and the constants of ammonia. There are great possibilities in the extension of this system under which men are trained as well as problems solved, and the benefits to industry are self-evident.

Much might be said of the educational advantages of the government laboratory in training men for research positions in industry. The bureaus of mines and standards often have been severely crippled by losing men to industry. It is not in general to the advantage of industry to so cripple an organization working for the benefit of industry.

It is trite to say that research, industrial or any other, is expensive, so is life insurance; but it is far more costly not to support research adequately, just as it is not to make provision for future contingencies. It has been said such government laboratories as the bureau of standards and mines are luxuries we can easily dispense with; yes, just as the farmer's seed and fertilizer can be dispensed with to his ruin. What does it cost per capita for the Bureau of Standards or the Bureau of Mines? It costs almost exactly a cent apiece for each inhabitant of this country, which if I were not a member of the staff, I would characterize as dirt cheap, the price of the tax on one 10-cent movie ticket.

The American Society for Steel Treating is concerned with many problems, some of them of great intricacy, involving not only the perfection of practice in the subject of heat treating but dependent also upon the new facts to be discovered relating to the properties of the various types of steel and the characteristics of many auxiliaries such as fuels, refractories, pyrometers, quenching media, furnace control and design; problems relating to geometry and mass of heating and cooling objects, and many others.

We, at the standards bureau, would be glad to see formed within this Society a committee advisory to the Bureau on Heat Treatment of Steel, which would enable us to keep in touch with each other so that the bureau's efforts in this field of investigation would be constantly in

harmony with the most progressive minds in the country interested in furthering progress in this subject.

Finally, the author wants to make a special plea for scientific research in industry at this time. We have been witnessing, during this period of depression, the cutting down and even entire wiping out of many research departments. How many times have we all heard the argument; in times of prosperity we have not the time and do not need research, and in hard times we cannot afford it? In my opinion, the wise board of directors is the one which stimulates research in hard times and even if it has to borrow money to do so. Competition will be keener than ever as prosperity returns and the company which has in the meantime sharpened its tools by increasing its research facilities will score in the long run. There is no greater economic waste than wrecking a going research group.

DISCUSSION OF THE RESEARCH SESSION

AT THE research session which was conducted on Friday morning of the Convention, four papers were presented dealing with various phases of the problem. Dr. H. E. Howe, chairman Division of Research Extension, National Research Council, presided at the meeting. Two papers are given in full elsewhere in this issue. Sufficient valuable discussion took place at the session to warrant publication of the stenographic notes which are in part as follows:

CHAIRMAN HOWE: It is obvious that in all periods from earliest times there have been constructive minds at work upon the problems which have presented themselves. Those men who domesticated the horse, the cow, and the dog must have compared favorably in intellect with leaders in later times. The same may be said for those who succeeded in developing domestic grains from wild flax, this work having gone on so rapidly, there is at present uncertainty as to the identity of the parent plants. The winning of metals from the earth and the adaptation of these metals to the service of man also required thinking of no mean order.

The bright spots in history may be said to be those resulting from the work of larger number of constructive minds rather than the other periods known as the dark ages. Here and there the structures which remain to this day often testify to these particularly fortunate periods in history and much of our present day progress has its roots in the inventions and discoveries made by constructive minds many years ago.

Perhaps there has been no time in history when so many constructive minds have been at work as at present. The present also offers greatest encouragement to such constructive thought. Those industries which are founded upon the sciences have made the greatest progress with the least waste of time and energy and some of the older activities which have behind them thousands of years of experience are beginning to find that even they can employ scientific and industrial research to undoubted advantage. We need only to compare the progress of the electrical sciences and arts in the last hundred years with what has been accomplished in textiles and ceramics in five or ten thousand years.

Steel treating, of course, is an excellent example of applied science and the members of the American Society for Steel Treating are to be complimented upon the progress that has been made in their art. It is obvious to all that further research is a necessity and an activity which holds out every promise of being profitable. The purpose of the present session is to encourage members of the society to further efforts and to suggest various means by which the fundamentals underlying the work can be studied, new laws established, and new principles developed by means of which the most difficult of the problems may be solved. The men who will speak at this session come from different fields of experience in research and all are known for what they have accomplished and all have very much at heart the success of any research which may be conducted by the members of the American Society for Steel Treating, individually and co-operatively.

The first speaker will be Dr. Hyde, of the General Electric Co., his headquarters being in Cleveland, and those of you who have followed the progress of illumination know that he has contributed a great deal

to it. Dr. Hyde will address this meeting on "Field Industrial Research."

Dr. E. P. Hyde, director of research, Nela Research Laboratory, Cleveland, presents a paper "Field Industrial Research." This paper will be published in the December issue of TRANSACTIONS.

CHAIRMAN HOWE: The next speaker of this symposium will be Professor Adams, chairman of the Division of Engineering of the National Research Council, and who is soon to return to Harvard University as professor of electrical engineering. He is going to speak to us on "The National Aspect of Research."

PROFESSOR ADAMS: I wish first to take exception to only one thing that Doctor Hyde has said, and that is that engineering is an art. I think perhaps he is right if he applies it to the average work of the engineer today, but it ought not to be applied to an engineer who hasn't the fundamental grounding, and the science underlying his profession must fail absolutely in solving those many problems that are presented to him. In many cases he doesn't even see the problem because he hasn't that habit of visualization and the necessary ground work and thus doesn't understand it. He need not be a scientist in the sense that Doctor Hyde mentioned.

Professor Adams reads paper and comments on it as follows:

There is one little thing with regard to fundamental engineering research, as I have called it, which I wish to read and to connect up my terminology with Doctor Hyde's, I am going to compare the two. I have called "scientific research," both the "frontier research" and the "intensive research", as the "development of the new fields opened up." I have referred to "fundamental engineering research" and to "industrial research," somewhat differently than Doctor Hyde, but I wish to make this distinction, which is important for the purpose of comparison between fundamental engineering research and industrial research. By fundamental engineering research I have in mind that great field of research work which is in large degree scientific and includes as well the determination of the properties of materials. I just have two illustrations here. We have under the Engineering Division of the National Research Council a research for the determination of fatigue in metals. That research is not aimed solely at the collection of a mass of material for giving the fatigue limits or endurance limits of materials. To do that over the whole field of all materials would be an almost endless job, but it has also, and really as the primary objective, the acquisition of a deeper knowledge in regard to the nature of the phenomenon and the relation of these fatigue or endurance limits to other more easily determined properties of material. Thus we hope to be able to predict or approximate the fatigue limits of materials that haven't been put through long and tedious tests.

Another illustration is our electrical insulation research, an almost exactly parallel research. The question of what we call dielectric losses is, in some respects, analogous to your fatigue phenomena, due to the constant alteration of stress to which almost all high tension insulation is subjected, 60 cycles per second, day in and day out.

We have also what corresponds to the impact tests, impact resistance power. The insulation is subjected to surges, certain energy behind it; these surges frequently give rise, after the first impulse, to very high frequency, much higher than the normal frequency of the circuit. So

we have phenomena that are in many respects exactly analogous to fatigue phenomena.

The distinction that I wish to make is that the fundamental engineering research deals not with the problems that are of particular interest to manufacturers—and in the industrial research I have included that research aimed at the solution of specific problems of immediate interest to the manufacturer, and in many cases involved in the development of ideas, practical or otherwise, many of which it is important from the corporation point of view to keep secret—whereas, what I have called fundamental engineering research I wish to confine strictly to that great field of information necessary to intelligent conduct of engineering work and the solution of a great many of our problems, which is not kept secret. For example, in our fatigue phenomena work, which was first financed by the Engineering Foundation with $50,000, the General Electric Co., seeing a great need for investigation in this field, increased the endowment by $30,000 more for a specific work, the results of which, however, were to be freely published.

These then briefly, are my distinctions, and the three groups that I have chosen were chiefly for the purpose of indicating the ways in which this work can best be carried out. For example, in fundamental engineering research the work is not being done to any large extent by individuals or corporations. Some work of that kind, of course, is going on in corporations all the time, but it is not comprehensive, and the comprehensive completion of any one of these big undertakings is so enormous, involves so much expense, that no individual corporation can touch it. I doubt even if the General Electric Co. could attack a problem of that kind, or would care to attack it in the comprehensive fashion that it should be attacked.

I might cite numerous illustrations of that kind, but I think it is safe to say that even at first, during the immediate period following the discovery of this sort, that the public becomes the recipient of the benefits. I know of many cases of that sort where the part of the profit, you might say, appropriated by the corporation is really a much smaller part than that which goes over to the public. An example of this is the very enormous volume of research work conducted by the Western Electric Co. on the telephone instrument that resulted, during a period of rising prices throughout the country, in enabling the telephone companies to continue their rates almost at what they were before.

Doctor Hyde has said in this connection that perhaps we are going too far with research. I think I got his meaning. He didn't mean we were doing too much real research, but that the research idea had spread so far throughout our industries that many men were conducting research and really weren't competent to do so, who really hadn't the scientific foundation, they were floundering around, more or less, and in many cases the results, while apparently some of them were of practical value, went no further, and in many other cases to my personal knowledge were absolutely misleading.

Dr. Hyde's paper will be published in December TRANSACTIONS.

Prof. A. E. White, director Department of Engineering Research, University of Michigan, Ann Arbor, Mich., reads paper "What the University Owes the Industries." This paper appears in full on page 85.

CHAIRMAN HOWE: Dr. G. K. Burgess, chief of division of metal-

lurgy, Bureau of Standards, Washington, is prevented from being with us, but his associate, H. J. French, will present the paper for him.

Mr. French reads Doctor Burgess' paper, "The Role of Government Laboratories in Industrial Research." This paper appears in full on page 91.

CHAIRMAN HOWE: Gentlemen, these various papers are before you for the regular discussion.

MR. LYNCH: I have been much interested in these four papers, and I think, as a rule, they were very clearly put. I think our first paper has outlined the proposition very nicely, with the exception of carrying, instead of a less distance, as our last speaker has suggested, a little further, and making processes to cover those things that have been discovered through research. A great many of our research problems, in my experience, have been such as to be carried to a point by a specialist that, when it becomes necessary to apply it, there is some little thing about it that doesn't work out. In order to make it work out it has been customary to bring in a process and make the specifications. In that way they do get them concrete and down to a clean-cut proposition. By doing that we extend that research in points that may not have been complete. Perhaps they were things that the man who is going to apply it didn't understand, and for that reason didn't make it a success and thereby make a practical application of a scientific research. That point I think perhaps was not covered quite completely enough. It would be my thought that those processes should be, and must be, practical, in order to get them in as research.

PROFESSOR ADAMS: It is wholly a matter of definition. It is just the different picture that one man forms in his mind from another's description. Take the dictionary definition of research and it would certainly cover all that Doctor Hyde covered in his diagram. It is merely a matter of what you agree to call research, but the dictionary certainly covers everything that is there. There is no question about that.

I wonder if you would bear with me for about three minutes while I will say a word about the engineering features of the National Research Council and the engineering societies. We have laid out a plan of organization and are now putting it into effect which ties up those engineering societies at present in a plan for organizing this part of the research that I have called fundamental engineering research, exclusive of those competitive problems which industries naturally prefer to handle themselves. The two illustrations which I gave cover that.

Now the scheme is briefly as follows. In each major field, for instance, in mining and metallurgy, mechanical engineering and electrical engineering, we have a rather large advisory board. That advisory board is usually attached—not always—to the society of major interest in that as its research committee, but at the same time the advisory board, through the Division of Engineering of the National Research Council—and the intention is that the membership of that Board be not confined to the society which we call the sponsor society, but should include representatives from all the other allied societies. That second step hasn't come in as yet, but that is a part of the program, and it is simply a matter of getting the societies to move in a new field.

The membership of these advisory boards is pretty broad and comprehensive, including some of the best experts in the country, including

the representatives of the allied societies. It will include also such representatives from the larger industrial units in that field. The functions of some of these advisory boards are briefly as follows: At first the object is merely to co-ordinate all the work in that field, to get the research talent in that field concentrated on the most important problems under the auspices of the society. The way these boards operated,—and one or two of them are already operating, and very satisfactorily—is this: They get together infrequently, once or twice a year, and comb over the suggestions that have been presented for researches in that field, all, as I say, in this fundamental engineering research. They select a limited number feasible to conduct, or likely to be in hand, and also those most promising, organize subcommittees, one for each of these subjects, with the best group of experts they can pick, plan for meetings and generally act in an advisory capacity to these subcommittees. Now that scheme is working out very well in one or two instances where it is in full operation; in the American Bureau of Welding, under the Welding Society, representing 20 other organizations in that case, and the American Society of Mechanical Engineers, where they had recently a research committee of their own, a central committee, with subcommittees, the whole combination being now attached to the Division of Engineering.

Our purpose is to have the societies themselves take the active part in this work, do all their work in connection with the industry, through to the raising of funds and the conduct of the work. It is impossible with the office staff available in the Division of Engineering to carry out all this work.

One illustration is our highway research program. For reasons of our connections through the Bureau of Public Roads, it was seen advisable to have it sponsored through the individual society, but there are a large number of societies on this advisory board, the Bureau of Public Roads, the Association of State Highway Officials and other interested organizations. That is operating in exactly the same way as the others except that in that case we have enough funds available, already available, to employ a competent high grade engineer for this Advisory Board to devote his whole time to this work, with a staff under him. That Director is Prof. W. K. Hatt, of Purdue University, and that is actually under way.

We have funds available for research all fully in sight now of over half a million dollars a year provided by the Bureau of Public Roads and the State Highway Departments, very largely, and the Department of Agriculture has actually contributed $12,000 a year to the expenses, and several of the states are contributing $1000 or $1500 apiece to that as well, so that the whole thing is run largely by the contributions from the federal government and the states. That is merely an illustration of a little different advisory board. But the whole purpose of the movement is the avoidance of this hit or miss method of conducting research here, there and elsewhere, and the overlapping of effort. What is even quite as important as this is to get our meager—and I speak advisedly—our meager research talent concentrated on the one job, with everybody helping on the job, everybody co-operating.

CHAIRMAN HOWE: I would like to add a word and call your attention to two activities which, on account of my connections, I am particularly interested in. One is called the Alloy Research Associa-

tion, which would have as its official work the gathering of all information that appears throughout the world in all the different languages on the subject of alloys and metals, and publishing that in critical, abstract form and through other committee means of presentation. That is put on by the Division of Engineering and the Division of Research. We have made a beginning in that work and have had to stop until the concerns who must underwrite that sort of thing feel that they can spend the $250 a year for a little trial period to see what can be done in co operation of this sort, co-operatively gathering and disseminating information in as large a field as metals and alloys.

In that connection, we have been told by some that they don't believe the business man wants information, that he gets so engrossed in his pursuit of the dollar that he forgets the point that he must have information to keep himself abreast of the times, and that information is one thing that cannot be obtained co-operatively and used in what may seem private business.

The other thing is something in which Doctor Hyde is particularly connected, being one of the trustees in that enterprise. There, again, the industries must help underwrite that proposition, which we estimate will cost $150,000 to $200,000, and of which a considerable portion is already in hand. But the financial campaign there has had to wait again until the industry feels better about undertaking that sort of work.

MR. MILTON: The president of the American Chemical Society, in an address before the institute in Pittsburgh on chemical research, made the statement that "unless American chemists go back and study the application of chemical research, we will not attain the high standards which we had during the period of the war," and it seems to me that something of this nature is applicable to all research for engineers, to study the methods of the man who has established engineering practices.

MR. STEELE: We have had some difficulties in engineering laboratories in the universities. The engineering research laboratory is interested in a lot of different things, but in every-day work something goes wrong with the bath and it is up to us to get results in a certain time, because everything we use costs money, and we must correct it at once. Now when we have such information in advance we can attack that problem and put our whole force on that problem and correct it. If we must go to two or three universities or other institutions, we don't know whether the man is capable of taking up such trouble or not; we haven't had the contact with him, haven't gotten statistics to know whether he can do it or not. If the trouble is of more of a general nature, one problem of the universities would be to let one man in the university get all the material he wants from the industrial concerns,—the concerns would be very glad to give him quite a bit of material to be of economic assistance, but they don't see the advantage in paying a man at the university to make the test until at least he has shown his worth.

We have in our engineering laboratory rather extensive work done. We could make some tests on fatigue. We have applied it to bearings, and that kind of fatigue tests probably will come out in the work taken up by the fatigue commission. We want to get the results which we can apply. We have a number of problems in connection with this fatigue matter which we would like very much to take up with the gen-

eral university laboratories or whatever it might be, because we cannot afford to hire a man to take up such special problems such as the minute qualities of the steel or various compositions of steel forgings.

LIEUT. COL. WHITE: I might just make this statement with regard to this matter. It has not been the intention in my paper to give a suggestion that by carrying out work at the universities the industrial laboratories or work at different manufacturing plants should be abandoned. I think it is quite generally agreed that the industrial laboratories are exceedingly essential and exceedingly important, and that for carrying on certain features of the plant operation it is exceedingly essential that they operate. I didn't touch on that phase of the subject, assuming possibly that that would be quite generally accepted.

CHAIRMAN HOWE: It seems to me that the problem is very much like the one that exists in medicine, where the physician is eternally busy trying to save the life of his patients. That is a parallel to your factory problem that comes up and must be solved by noon the next day. But there are a number of fundamental problems in medicine upon which someone must be at work, not necessarily with human material, and they will undertake to determine the underlying laws of those problems as a long time research, and therefore we have medical research experts who are working on those problems, and all physicians are making use of those in trying to cure their patients. I think there probably are some fundamentals which should be supported and which must take a long time to solve, while we are trying to solve the immediate problems in the factory. I think the same thing holds true with regard to fatigue research, with magnetic alloys.

OUTLINES AIMS OF S. A. E. RESEARCH DEPARTMENT

(This article is reprinted from a News Bulletin issued by the Society of Automotive Engineers, 29 West Thirty-ninth street, New York. It is of pertinent interest in connection with the Research Session held at the Indianapolis Convention, a report of which appears in this issue of TRANSACTIONS.—Editor.)

PRESIDENT BEECROFT, of the Society of Automotive Engineers, has expressed the view that within less than 10 years the research department which that society has established recently will be of as great magnitude and value to the industry and the country as the society's standards department which is just entering its second decade. Dr. H. C. Dickinson, manager of the S. A. E. research department, in an address before the Detroit section of the society at its opening session of this season, outlined the purposes, aims and possibilities of the department. He said that, in general, the testing of an individual device or any particular material is not included in the definition of research. On the other hand, the study of methods of test as well as the deduction of general information from a systematic series of tests is properly so classed, although to be of value as research the results must be put in such form that they can be of general application.

Development research is recognized as clearly an exclusive function of the individual engineer and the industrial laboratory. By far the largest part of the work of all laboratories connected with the industry is of this nature and as such is recognized by the department as essentially confidential, whereas it is coming to be more and more generally recognized—although we regret, sometimes more as an abstraction than as a course of action—that there is much more to be gained than lost through a free interchange of all research information which is capable of general application. The S. A. E. research department will therefore confine its efforts to explorational and intensive fundamental research. Much work of this nature which is in progress in the industrial laboratories will be of interest to the department and it is hoped that much more such work will be undertaken in the future. But with the major part of the work of these laboratories which is development work, we will not concern ourselves.

An unbelievable amount of time and effort is wasted in the trial of expedients which a more careful application of the fundamental laws of physics and chemistry would have shown at a glance were based on incorrect assumptions. This fact was startingly illustrated during the war when thousands of inventions of every conceivable sort were presented for consideration of the government. It is safe to say that at least 90 per cent of these proposals showed such obvious and fatal errors in fundamental physical and chemical principles that they could be condemned absolutely at a glance. Of course most of them could be condemned equally on practical grounds but one's judgment as to practical possibilities is by no means so safe a guide. Many things which look impractical do actually work but so far as we know nothing works which violates the law of conservation of energy, or the second law of thermodynamics, or Newton's laws of motion, barring Einstein, or any other of a few hundred such principles. Successful engineering research, as well as economical development work, requires men with a peculiar combination of broad fundamental knowledge and sound common sense,

with the enthusiasm of the typical inventor but without his typical shortcomings.

The most common incentive for the organization and continued support of research laboratories or of any systematic research program is necessarily the commercial one. In fact this is almost the only one if we except some of the educational laboratories which have been endowed purely for the sake of the advancement of science. Thus almost every research laboratory and particularly the industrial ones present a constant conflict between these two points of view which are somewhat incompatible. The true research worker is interested in securing facts and will not be satisfied until his results are complete. Moreover, every problem he undertakes presents to him numerous side-lines which are of absorbing interest. If given his own way, unless he is endowed with unusual self-control, he will either carry through his problem to a final conclusion or switch to some side-line of greater interest, according to his temperament. On the other hand, the director of the laboratory or the "man who pays the bills", unless endowed with unusual patience and foresight, will, as soon as some fact of apparent commercial value is developed, recommend dropping the research and developing something useful. A happy compromise between the two points of view is difficult to attain, but a real compromise is necessary since both viewpoints are important and neither side may be neglected.

Up to within the past few years the United States, which has shown by far the greatest industrial development in automotive lines, has contributed comparatively little to the sum of automotive research. The work of British and German experimenters had to serve the needs of our own engineers even though it was entirely inadequate for our needs. In the past few years, however, there has been a general awakening to the need of research among members of the society. We are now awake to the need and once awakened the United States will not lag behind. In fact, perhaps a warning is needed that while the possibilities of research can hardly be overestimated, the realization of these possibilities in terms of industrial results, rests with the engineers in charge of design and development. No matter how many and able the research engineers, nor how important their conclusions, these conclusions will be of value only insofar as they are embodied in successful design.

Aims of the Research Department—In general, the object of the S. A. E. research department is to secure through concerted effort more, and more reliable, fundamental technical information for the use of the members of the society and to make this information more easily available. The distribution of information may be handled in several ways. Fundamental research is in the last analysis almost entirely a question of men rather than of equipment. Many of the most important scientific results have been obtained without laboratory equipment worthy of the name. A study of the research situation in the various laboratories leads to the conclusion that these laboratories are even now sadly undermanned, particularly with men of real ability. To establish a new laboratory could not increase the supply of first-grade research men hence is would have to be manned at the expense of existing institutions. Thus, whatever results the new laboratory might attain would be at the expense of other institutions and the net result probably would not be increased research. It appears therefore that the department can most profitably devote its efforts to assisting existing laboratories.

The three classes of laboratories—educational, industrial, and independent—occupy altogether different positions in regard to research, and any general plan must take account of these differences. It is recognized that the prime object of the industrial laboratories, those directly connected with the various manufacturing companies, must always be development research. But in connection with these we hope there will be accomplished an ever-increasing amount of fundamental research work which can be made of general value,—such work as deals with general principles rather than specific questions of design. It is a common experience to find one laboratory undertaking a research intended to cover some problem which has been carefully covered elsewhere, but no record of which is available. It is one of the aims of the research department to secure, so far as possible, the publication or at least a record of such nonconfidential general results and to act as a clearing house of information on research problems of this character. For the most part, the various laboratories are rather well supplied with problems, but from some institutions where new facilities or new men have become available, there have come requests for suggestions as to problems or general lines of work which might be taken up to advantage. It would seem that here is a splendid opportunity for better use of the educational laboratories by the industry. The custom of farming out individual research problems has been followed to some extent but there is room for much more of it. The S. A. E. research department stands ready to offer any possible assistance in securing more co-operation of this kind.

Duplication of Research—Recently very much caustic criticism has been heard regarding duplication in all sorts of connections, including research. One might make remarks about the duplication in criticism. Research is always a matter of duplication since no physical fact is ever established except through repeated observation. Much apparent duplication is not only desirable but necessary. Nevertheless, this applies to intelligent duplication only. Not much is to be gained by having several different laboratories working on the same problem unless each knows something about what the other is doing. This latter sort of duplication should be avoided particularly among the educational laboratories so far as possible. Since the results of most research are not to be had in print for months or perhaps years after the work is begun, the most pomising means of preventing unnecessary repetition seems to be through some central clearing house for work proposed and in progress. This function the S. A. E. research department will hope to fulfill.

General Research Program—One of the important objects of the S. A. E. research department is to assist toward the development of a more systematic program of research throughout the industry. The formulation of such a program is too much of a problem to be solved for some time to come. It must be built up little by little with the co-operation of the members of the Society of Automotive Engineers.

THE OPTICS OF METALLOGRAPHY

By W. L. Patterson

IN THE best known books on metallography one finds little information concerning the optical instruments used in this study. Some books show illustrations of various types of microscopes, etc., but little is said concerning the manipulation or means of securing the best results with the microscope, the illuminant or the camera. The microscope is an important part of the metallurgical equipment, for by its use we are able to analyze metals according to their structural composition and to make determinations not possible by chemical analysis.

The important parts of the microscope are the optical parts and of these the objectives are probably most important, for it is by the objective that the image is first formed; and the quality and use of the objective determines the final result. The objective is so called because it is nearest to the object. Figs. 1, 2 and 3 show respectively the 16, 4 and 1.9 millimeter objectives of the usual type, but objectives are made in a variety of focal lengths, numerical apertures and styles of mount by various makers. Following are given the usual focal lengths and numerical apertures of achromatic objectives:

Focus Lengths Millimeters	Numerical Aperture	Type of Lens
	0.10	Single achromatic lens
32	0.25	Two achromatic doublets
16	0.50	These three have non-achromatic front with two achromatic doublets
8	0.85	
4	0.85	
3	1.25	6 lenses in all
1.9	1.32	Flourite construction, semi-apochromatic
1.9		

Further reference will be made to the apochromatic objectives later. The focal length of an objective does not indicate its working distance, but means that the combination of lenses composing the objective is equal in focus to a single lens of the stated focus. Thus the working distance for the:

16 millimeter focus = 7 millimeters
4 " = 0.30 "
1.9 " = 0.15 "

An objective may be said to possess seven qualities: Magnifying power; aperture or numerical aperture; resolving power; depth of focus, or penetrating power; illuminating power; flatness of field; and defining power. To fulfill all of these requirements in a satisfactory manner necessitates considerable skill upon the part of the optician. These qualities will be discussed one by one.

Magnifying power usually is stated in the catalogs of various makers in terms of the combination of a certain objective, certain eyepiece and tube length at a predetermined image distance. While tables given in the catalogs are approximately correct, the magnification stated will be obtained only if the conditions given are fulfilled. If the tube length, that is, the distance between objective and eyepiece, is increased or decreased, or an increase or decrease in image distance is taken as in photography, the magnification tables will not prove correct. Tables given in catalogs are often for visual

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A paper presented before the Rochester, Detroit, Pittsburgh, Philadelphia, Cleveland and Indianapolis Chapters. The author, W. L. Patterson, is connected with the Bausch & Lamb Optical Co., Rochester, N. Y.

work and are based on an apparent or virtual image being formed in space at a distance of 250 millimeters from the eye. This apparent size will vary with persons having near or far-sighted eyes, but the normal distance is taken as 250 millimeters and the size of the image is the same if projected on the ground glass of a camera at 250 millimeters.

Makers of objectives also give in their catalogs the initial magnification of their several objectives, that is, the magnification they give at a certain distance unaided by the eyepiece. These tables of initial magnification will be found to vary in different catalogs even though objectives are of the same focal length, this being due to the different systems of calculating magnification. It will be found, however, that for the same focus of objective, the same focus of eyepiece and the same tube length, the figures nearly agree. Some makers use a number system for both eyepieces and objectives, but in making comparisons only focal lengths should be considered.

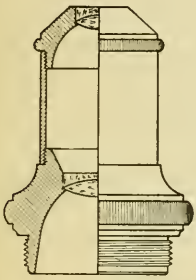


Fig. 1

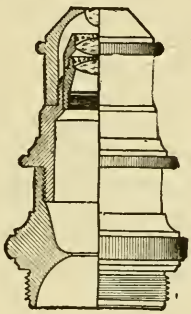


Fig. 2

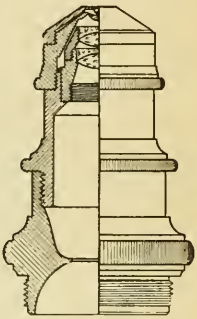
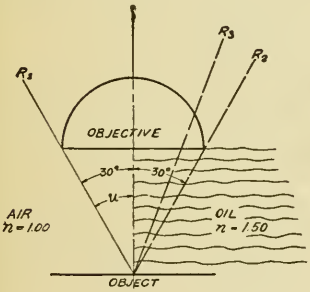
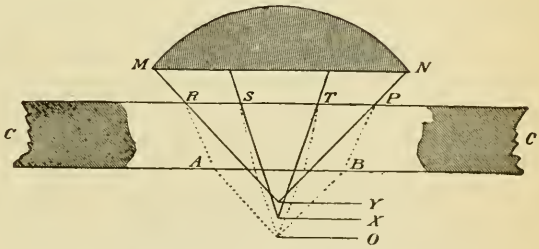


Fig. 3



$N.A. = n \cdot \sin u.$

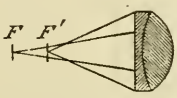
Fig. 4



The effect produced by a cover-glass on the corrections of an object-glass.

Fig. 5

Aplanatic system.



Under-corrected system

Fig. 6

Fig. 1—16-millimeter objective of usual type. Fig. 2—4-millimeter objective of usual type. Fig. 3—1.9-millimeter objective of usual type. Fig. 4—Diagram showing theory of numerical aperture. Fig. 5—Effect of coverglass upon focus. Fig. 6—Undercorrected system obtained without use of coverglass

In the large inverted forms of metallurgical microscopes the distance between objective and eyepiece is usually about 40 millimeters longer than in the ordinary table microscope and, therefore, the magnification is increased some 25 per cent even with the same focus of objective and eyepiece; hence the difference in magnification tables for this microscope. With the many variable factors in different outfits, it is difficult to make comparisons and it is best to calculate the magnification for the particular outfit being used especially as regards camera magnifications. To obtain the exact magnification at the ground glass of the camera and therefore of the photograph it is best to project a stage micrometer upon the ground glass and measure its magnified image. Micrometers graduated upon metal may be obtained for this purpose. The rulings are in tenths and hundredths of a millimeter. They are placed upon the stage and illuminated the same as a metal specimen. After focusing upon the ground glass the magnification can be measured directly without further calculation.

The aperture or numerical aperture is a property to which many buyers of microscopes probably pay little attention, but it is nevertheless an important quality of an objective. The diagram in Fig. 4 is shown in an attempt to simplify the theory of numerical aperture. If we assume that few if any objects are perfectly smooth, then light is dispersed from every point on the surface of an object in all directions up to 180 degrees. Only an extremely narrow pencil of this can be received by the unaided eye. The apparent problem of practical optics is to be able by means of lenses to gather and bring to a focus as many of the unadmitted rays as possible. In early investigation it was found that the objective which gathered in the greatest angle of rays gave the greatest resolving power.

If only dry objectives were to be considered, we might make a comparison on the basis of angular aperture, that is, the angle of the cone of light which is admitted to the front lens of the objective and reaches the eye. This is important as internal diaphragms reduce apertures, but these apertures may be measured readily by special instruments.

A thorough study by Professor Abbe, however, proved that the only exact method for comparison of objective apertures was by comparison of the sines of the extreme admitted radiant pencils and, when the media differed between the object and the objective, the refractive indices of those media, which are 1.00 for air, 1.33 for water and 1.50 for cedar oil. It is very evident that rays emanating from an object and passing to the objective will travel in a different angle according to the medium through which they pass, owing to the different refractive indices or bending powers of such media.

In Fig. 4 is shown a ray R_1 leaving the object at an angle of 30 degrees, passing through air and just entering the extreme edge of the front lens of the objective. A second ray R_2 leaving the object at the same angle and passing through oil will be bent so as to fall well within the edge of the objective lens, as shown by R_3. It is obvious that a ray leaving the object at a still greater angle than R_2 and passing through oil will be bent so as to pass into the objective. Thus a wider angle of rays is collected in case of the oil immersion objective than in the dry objective.

It will be seen that angular aperture would not be a comparative measure for the two kinds of media. Abbe found that a value could be expressed for the different conditions by taking the sine of one-half of the angle of aperture

and multiplying it by the refractive index of the media between object and objective; hence the formula:

$$\text{Numerical aperture} = n \sin u$$

where n = Refractive index of media air 1.00, water 1.33, oil 1.50
and u = One-half of angular aperture
Thus in the slide the numerical aperture on the air side would be

$$1.00 \times \sin 30^\circ = 1.00 \times .5 = 0.50$$

and on the oil side

$$1.50 \times \sin 30^\circ = 1.50 \times .5 = 0.75$$

This gives a method of comparison between dry and oil immersion objectives. As stated a few minutes ago, numerical aperture plays an important part in the results obtainable with a given objective. The resolving power, which is the property by which an objective shows distinctly separated two small elements in the structure of an object, is directly proportional to the numerical aperture; thus an objective of 0.50 numerical aperture as in the 8 millimeter, has twice the resolving power of the 16 millimeter or 0.25 numerical aperture.

If a very narrow central pencil is used for illumination, the finest detail that can be shown by the microscope, with high enough magnification is equal to $\frac{\text{Lambda}}{\text{numerical aperture}}$ where Lambda is the wave length of the light used for illumination, say one-half micron. The wider the pencil used for illumination, the greater the resolving power until a maximum is reached, when the width of the pencil is sufficient to fill the whole aperture of the objective. In this case the resolving power is twice as great, the finest detail that the objective can show being now equal to $\frac{\text{Lambda}}{2 \times \text{numerical aperture}}$ For an 0 50 objective the first would be one micron with reduced aperture and the second one-half micron with full aperture.

For practical purposes we may take the rule that the numerical aperture multiplied by 100,000 will give the number of lines per inch which can be resolved theoretically by a given objective. Thus, pearlite of say 25,000 laminations per inch should be easily resolved with an 8-millimeter objective of 0.50 numerical aperture and a suitable eyepiece and bellows draw can be used to magnify the image to the size desired, say 400 diameters. On the other hand, an objective of say 0.25 numerical aperture could scarcely be expected to resolve this structure no matter how high we magnify the image by eyepieces or bellows extension. The magnification should never exceed 1000 times the numerical aperture; preferably it should be somewhat less dependent upon the quality of the objective.

Depth of focus (known also as depth of sharpness or penetration) is another important factor which is often not clearly understood. It depends on the numerical aperture and the magnification and is inversely proportional to both. The formula used to express depth of focus is $\frac{1}{\text{numerical aperture}}$; therefore, the higher the numerical aperture and the higher the magnification, the less the depth of focus. It is beyond the power of the optician to change these conditions. Every effort aiming at an increase of the depth of focus, for instance, by inserting diaphragms above the back lens of the objective, must necessarily decrease the effective diameter of the back lens

and thus decrease the numerical aperture, thereby lowering the efficiency of the objective as regards resolving power. It may be advisable at times to introduce such diaphragming for the work to be done, and it will be shown later how such a change can be made by proper use of the illuminating system. However, objectives that show greater depth of focus than others of the same numerical aperture are not well corrected for other qualities.

The illuminating power of an objective is equal to the square of the numerical aperture, and objectives can be so compared; that is, a lens of 0.25 numerical aperture has an illuminating power of 0.062, while one of 0 50 numerical aperture has 0.25 or 4 times as great provided it is used at the same magnification. "Flatness of field as such," said the late Dr. Carpenter, "is an optical impossibility." But by using compensation eyepieces to

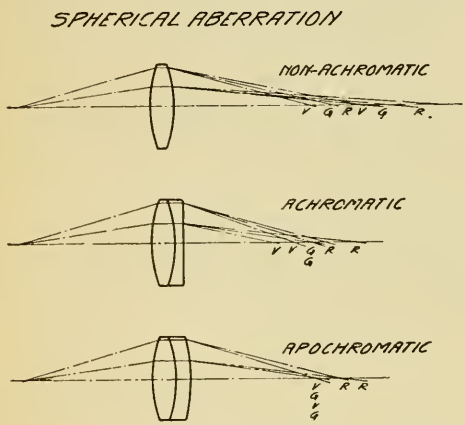


Fig. 7

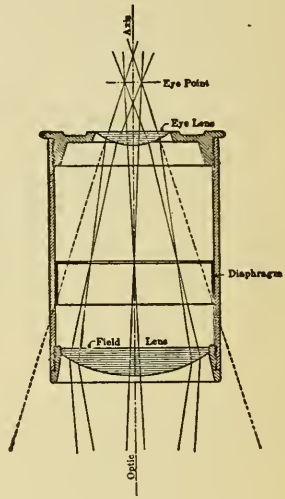


Fig. 8

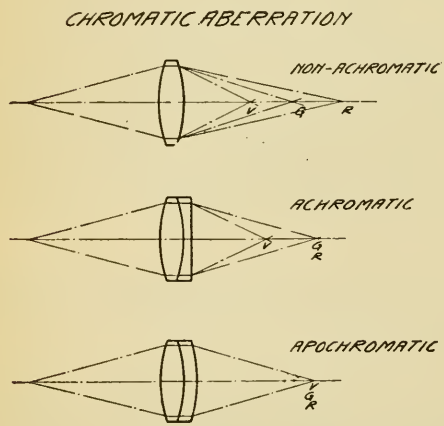
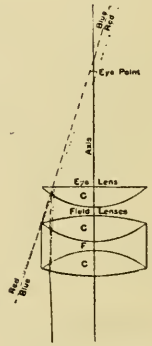


Fig. 9



POSITIVE COMPENSATION OCULAR.
(From Spitta, p. 110).

Fig. 10

Fig. 7—Illustration of apochromatic lens. Fig. 8—Eyepiece of Huygenian form. Fig. 9—Correction for spherical aberration. Fig. 10—Compensation type eyepiece

Fig. 11

Fig. 12

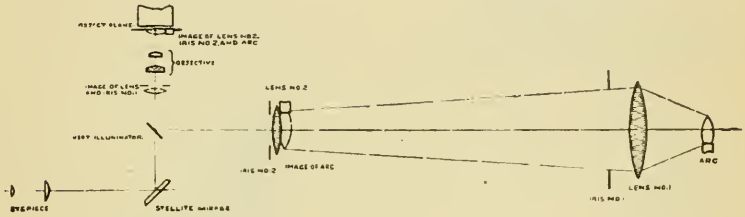


Fig. 13

Fig. 11—Vertical illuminator to which can be fitted mirrors, reflector, plane glass reflector, lenses and diaphragms as desired. Fig. 12—Condenser and iris diaphragm mounted in a separate standard. Fig. 13—Method for obtaining critical illumination

correct the margin of field and by increasing the depth of focus by reducing the aperture, apparent flatness is secured but at the expense of resolving power, as stated before. As an illustration of this we refer again to the statement concerning the depth of focus, which is equal to $\frac{1}{\text{numerical aperture}}$; hence, for an objective of 0.50 numerical aperture, the depth would be 2, while for an objective of 0.85 numerical aperture, the depth would be 1.17.

As depth of focus also varies with the magnification, if we use the above lenses at the same magnification we should naturally have greater depth in the objective of 0.50 numerical aperture and if this gives sufficient resolving power for the work in hand it may be used to obtain a flatter field.

Defining power depends upon the finest correction of spherical aberration and chromatic aberration, the perfect centering of the lenses of the objective, and in fact, on the general excellence of the mechanical work involved in the making, and it is here the optician must show his skill. It should be borne in mind that the finer the definition of an objective, the more sensitive it is to incorrect focusing and to slight changes of the adjustment through vibration, etc. In constructing objectives their formulae

should be based upon rigorous computations, all elements of construction such as glass, radii, thickness of lenses separation, etc., being determined in advance wholly without recourse to experiment. This method of construction is the only one insuring uniformity in optical systems of such intricacy as a microscope objective.

It will be well to consider at this time the effect of tube length, that is the distance between objective and the eyepiece with which it is used. Most of the objectives used on biological and smaller metallurgical microscopes are corrected for a mechanical tube length of 160 to 170 millimeters. By mechanical tube length is meant the distance from the shoulder against which the objective screws to the shoulder against which the eyepiece rests. In the case of the larger metallurgical stands of the inverted type this distance is usually longer, owing to reflections necessary to secure an inverted stage and a convenient position for the viewing tube. Therefore, the objectives used on this type of microscope should be corrected for this extra length The use of objectives at incorrect tube length, especially in powers over 100 diameters, will result in inferior definition. This is especially true in metallographic work.

Objectives for metallurgical work must also be corrected for use without coverglass, as specimens of metal are examined without covering.

All objectives used in biological microscopes are corrected for the refraction which takes place when the ray from the object passes through a thin piece of glass. These objectives are not suited for use on uncovered objects and if used in metallurgical work only inferior results will be obtained except with the very lowest powers, such as 16 millimeters or lower. To show the effect of coverglass, Fig. 5 has been taken from Carpenter's book on the microscope. It will be seen that without the coverglass, an ordinary microscope objective would focus at different planes for the central and marginal zones as shown at points *y* and *x* but with the refraction of the coverglass the rays all focus at the point *o*.

Therefore if the ordinary objective is used without coverglass, it will work as an undercorrected system as shown in Fig. 6, whereas when corrected for use without cover the objective should be perfectly aplanatic as shown at the left, all rays focusing at one point. This correction cannot always be accomplished by changing distances between lenses but requires special computation. The oil immersion objective, however, needs no special correction as regards coverglass, because the immersion oil and coverglass are of the same refractive index and if the cover is missing, the additional strata is made up by a thicker layer of oil. The tube length, however, must be correct even in this case.

As to the objective mounts, both long and short mounts are used in metallurgical work. The short mounts should always be used with mirror or prism illuminators so as to bring the illuminator as near to the back focus of the objective as possible. The tendency of late, however, has been to use short mounts for all kinds of illuminators, although Professor Sauveur of Harvard University until recently preferred the long mount with plane glass illuminator. The objectives previously described are of the achromatic type, but the same characteristics are also found in the apochromatic objectives and they are even more sensitive to deviations from the standards for which they are made. The usual focal lengths and numerical apertures are as follows:

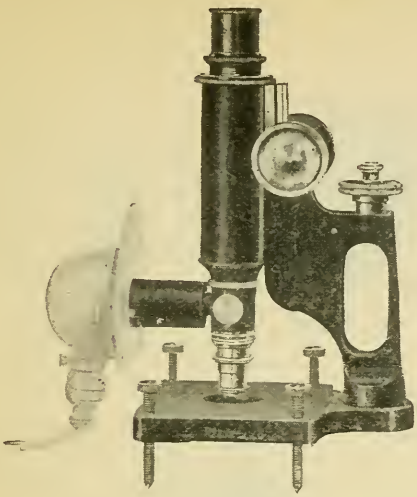


Fig. 14

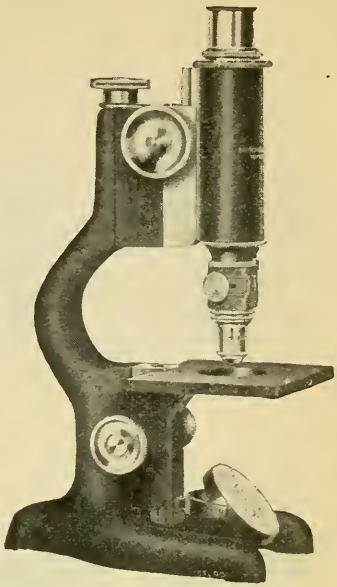


Fig. 15

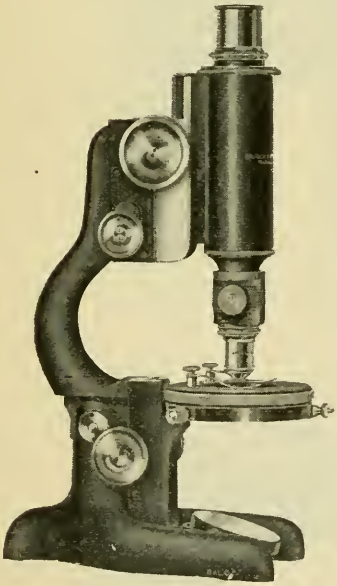


Fig. 16

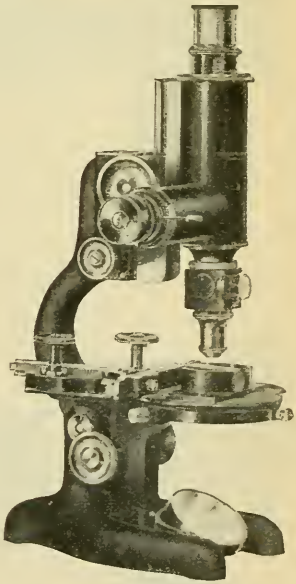


Fig. 17

Fig. 14—Tassin microscope with illuminating device attached to vertical illuminator. Fig. 15—Typical metallurgical microscope for student use. Fig. 16—A stand similar to that in Fig. 15 but having more delicate adjustment and a revolving stage with centering screws. Fig. 17—Fig. 16 with a mechanical stage attached

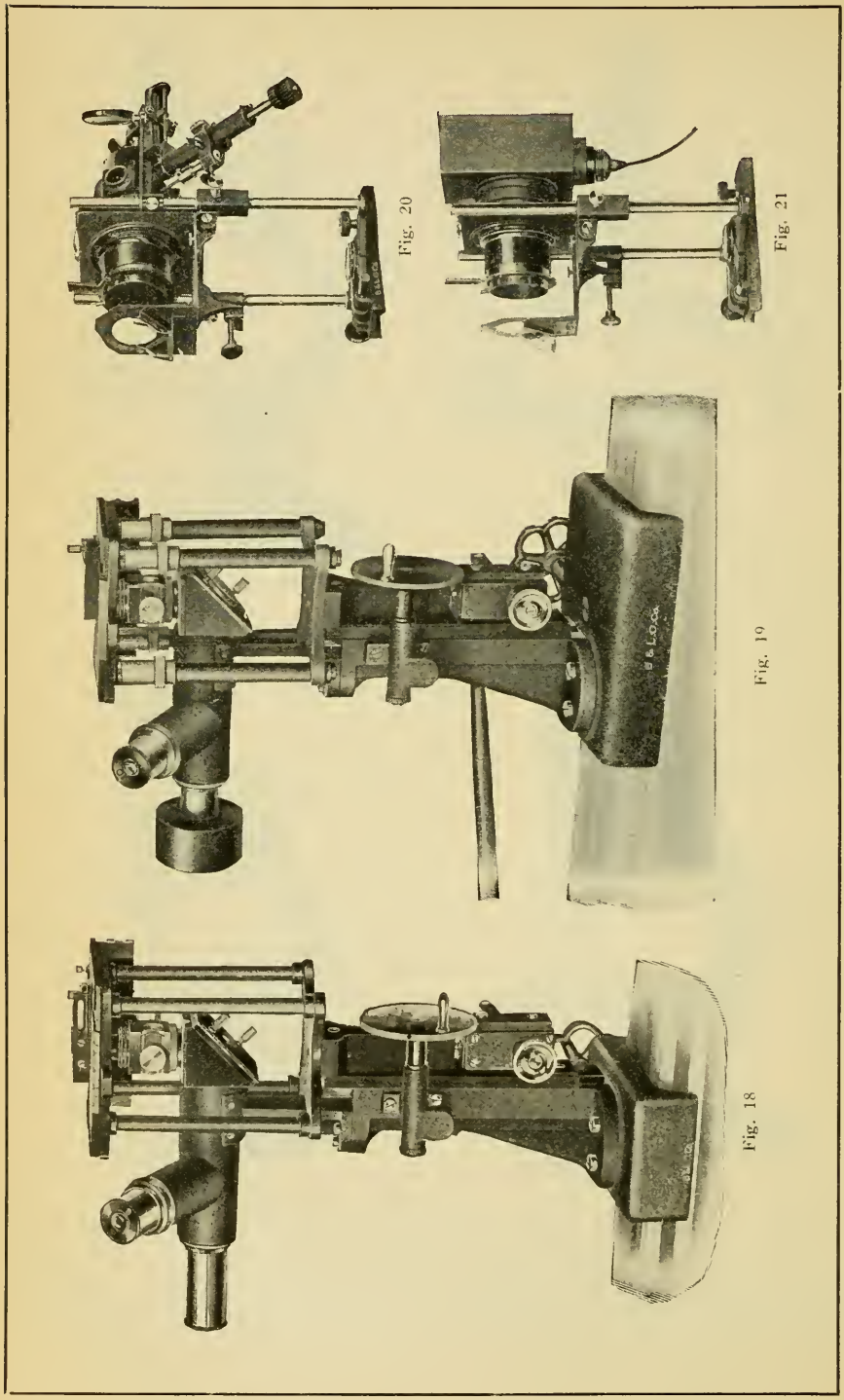


Fig. 18 Fig. 19 Fig. 20 Fig. 21

Fig. 18—Large inverted stand embodying all desirable features of metallurgical microscope. Fig. 19—A modification of the stand shown in Fig. 18. Fig. 20—An illuminant with arc lamp. Fig. 21—Adaptation of 6-volt lamp to same stand as the arc

Focus Length	Numerical Aperture apochromatic	Numerical Aperture achromatic
16 millimeters	0.30	0.25
8 "	0.65	0.50
4 "	0.95	0.85
3 "	0.95	0.85
2 "	1.30	1.25

It will be seen that the numerical apertures are somewhat greater in the apochromatic objective. This means increased resolving power and other features attending higher aperture. These lenses have other improvements than increased aperture. The word apochromatic means free of color and is illustrated by Fig. 7. If we were to form an image with an ordinary lens of nonachromatic form, a ray of white light coming from the object would be broken up into the several colors of the spectrum and images would be formed at different distances from the lens corresponding to each color. There would thus be a series of images, one behind the other, ranging from violet to red, the shorter waves being refracted more than the longer ones.

In the standard achromatic objective, two of these colored images would be combined and in apochromatic objectives, three colored images would form in the same plane and as the violet rays are brought to a focus at the same plane as the apple green visual rays, these objectives are excellent for photographic purposes, even when used without filters. As shown by Fig. 9, the correction for spherical aberration is more perfect. Spherical aberration refers to the fact that in an ordinary uncorrected lens the portion of a ray coming through the center and the portion coming through the outer zones are focused at different planes. In the uncorrected lens this applies to all colors; in the achromatic objective the correction is made for one selected color, say green, and in the apochromatic for two colors. Therefore, for the very finest class of investigations the apochromatic objectives are essential owing to their finer color and spherical corrections. These corrections are accomplished by the use of special glasses and a transparent substance known as flourite. Another series of objectives now offered upon the market is the 4-millimeter dry and 1.9-millimeter oil immersions, known as semi-apochromatic objectives. They have one flourite element and are much better than the regular achromatic objectives. They make a good compromise where cost will not permit the purchase of apochromatics.

The second part of the optical equipment to be considered is the eyepiece, so called because it is used near the eye. This may, however, lead to some confusion, as the eyepiece is also necessary when forming the image upon the ground glass of the camera. Some users of this class of apparatus have been found who thought the eyepiece was needed only in visual work. Small photographic lenses are used without eyepieces as later explained. The ordinary eyepiece shown in Fig. 8 is known as the Huygenian form, after its designer. It consists of the two nonachromatic planoconvex lenses with a diaphragm for limiting the field between them. The upper lens is known as the eye lens and the lower as the field lens. Huygenian eyepieces are made in a variety of powers as: 5X, 6.4X, 7.5X, 10X and 12.5X, these designations meaning that they magnify the image formed by the objective by these amounts. Different makers used different designations for their eyepieces and this is liable to cause confusion among different workers if attempt is made at comparison.

In the case of Leitz and Zeiss the eyepieces are numbered from 0 to 5 but the eyepieces of the Bausch & Lomb Optical Co. are marked with their mag-

nifying power as 5X, 10X, etc. Another and better form of eyepiece is known as the compensation eyepiece shown in Fig. 10, so called because it compensates for the variation in size of the blue and red images given by the apochromatic objective. While the apochromatic objective is so constructed as to bring these colors in focus at the same plane as previously stated, the images formed are not of the same size, and this is neutralized by the compensation eyepiece. They should, therefore, always be used when one is using apochromatic objectives and they may be used to good advantage with the high power achromatic objectives. The compensation eyepieces of various makers are not always interchangeable with different apochromatic objectives.

These eyepieces vary in construction and in the number of lenses according to their power. They are made in powers from 5X to 25X, much higher than the Huygenian type, and it is possible to use these high powers with the apochromatic objectives owing to their finer color correction. The slide shows the construction of the higher powers. The compensation eyepiece of Zeiss and Leitz are numbered 2, 4, 6, 8, etc., as in the Huygenian form, but Bausch & Lomb company mark theirs with the magnifying power, as 5X, 10X, etc.

There is another type of eyepiece known as the projection eyepiece, in which the eye lens or lens nearer to the photographic plate is adjustable according to the bellows extension of the camera. With this adjustment one is able to use the objective in the same relative position to the object as it is when used for visual work. Some of these eyepieces have a very small opening in the diaphragm which is liable to indicate that the field is unusually flat.

It is possible to get similar effects as those produced by the projection eyepieces with the ordinary eyepiece, by partially withdrawing them from the eyepiece tube when making photographs. This distance may be found by the formula:

$$\frac{\text{square of eyepiece focus}}{\text{length of camera draw}}$$

Thus for a 5X eyepiece of 50 millimeter focus and a bellows draw of 250 millimeters, the eyepiece would have to be extended 10 millimeters, or it may be determined by experiment. It will be seen that the distance becomes greater with low power eyepieces and short bellows draw. This adjustment keeps the objective in the same relation to the object as when used in visual work, as previously stated, and preserves its best spherical correction tending to flatten the fields. Too much stress cannot be laid upon the necessity of keeping all of the optical parts clean and free from dust, grease or finger marks. Poor results are due to this neglect.

In Carpenter's book on the microscope it is stated that the first vertical illuminator was made and used by Prof. H. L. Smith of Geneva, N. Y. Smith's illuminator consisted of a piece of speculum metal so placed as to reflect light down through one side of the objective, the image returning through the opposite side. The plane glass illuminator is said to have been designed by Beck of England. In this form the light is reflected by the surface of the glass through the objective and the image returns from the specimen through the glass to the eyepiece. Formerly much flare was experienced in using this type of illuminator, but it can be eliminated by proper illuminating appliances and diaphragms. Both forms of illuminator are in use

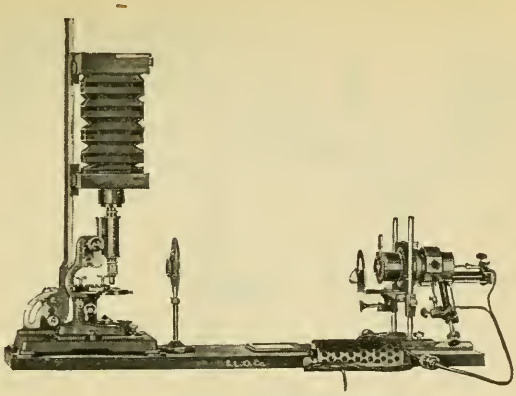


Fig. 22

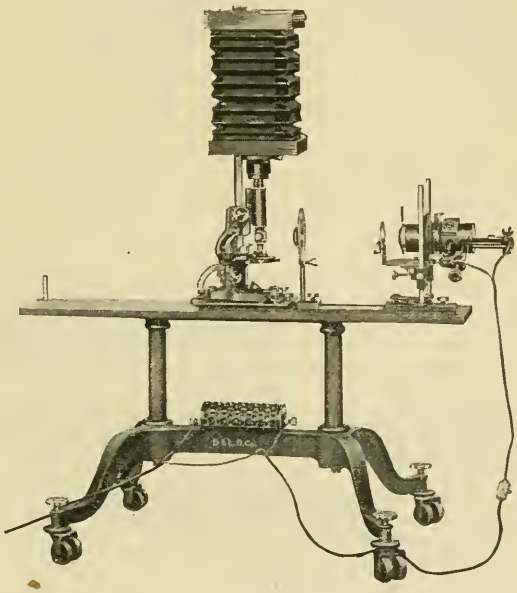


Fig. 23

Fig. 22—Simple type of vertical camera. Fig. 23—A low form of stand with vertical camera

today, the first in the form of mirrors and prisms and the latter much in its original form.

The mirror and prism types are preferred by some workers, and while they are satisfactory for low powers and relief work, they reduce the available aperture of the objective by nearly one-half with consequent reduction in resolving power. They do give increased illumination due to total reflection and may be used for projecting metal specimens with low powers

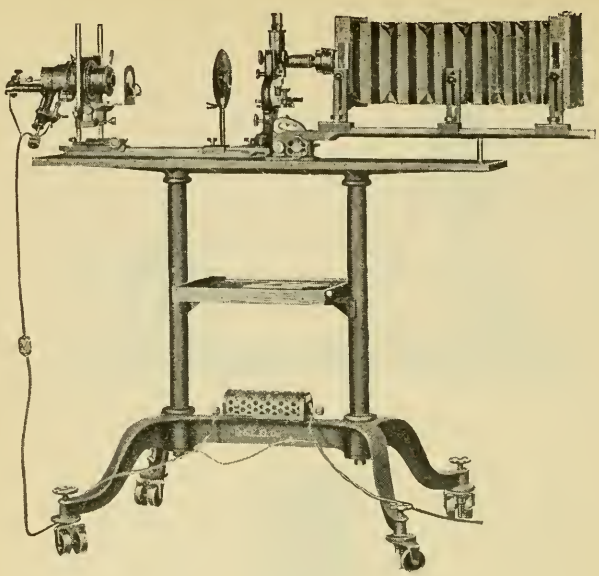


Fig. 24

Fig. 24—A camera specially designed for use with side tube microscope

when several observers wish to study the image,' a useful method of demonstrating to executives. For high powers and utmost resolution, the plane glass reflector is best.

Vertical illuminators have appeared from time to time in many forms. The one shown in Fig. 11 is a base model to which can be fitted mirrors, reflector, plane glass reflector, lenses and diaphragms as desired. For visual work and for outfits like the Tassin side tubes with lenses may be attached and used successfully, but when high power illumination is used and the beam of light must be carefully centered to the objective, the best results can be obtained by having condensers on separate standards so that they, as well as the movements of the vertical illuminator, can be adjusted independently. A recent addition to this type of illuminator consists in clamping screws whereby all adjustments can be locked so that once adjusted the illuminator cannot be deranged easily. Care must be exercised to keep the glasses of the illuminator clean and to prevent distortion by bending the mount when cleaning, as it will tend to destroy the definition.

Fig. 12 shows a condenser and iris diaphragm mounted in a separate standard in place of mounting it integral with the vertical illuminator. This is termed by the makers a supplementary condenser, to distinguish it from the condenser at the arc lamp. Its use and adjustment will be explained later.

It is generally agreed by expert microscopists that the best results are obtained when the specimen is examined or photographed with critical illumination. Critical illumination is obtained when the image of the illuminant and specimen are about in one plane, also when removing the eyepiece

and examining the back lens of objective through a pin hole cap, it is possible to entirely fill the lens with light. In Fig. 13 is shown how this kind of illumination may be obtained. The arc or Pointolite illuminant is nearly imaged on the supplementary condenser No. 2 by the aspheric condenser No. 1 with a distance of about 25 to 30 inches between the two lenses. This should give an image of the illuminant of about 25 to 30 millimeters diameter. The image should be slightly ahead of the supplementary lens No. 2 if an arc is used so as to avoid imaging gas bubbles upon the specimen.

An image of the fully and evenly illuminated aspheric lens No. 1 and its iris diaphragm referred later are projected into the back focus of the objective by means of the supplementary condenser No. 2 and the vertical illuminator. The supplementary lens is of such focus and set at such distance from the objective, that is, the same optical distance as the eyepiece diaphragm from objective, that the image of the arc, the evenly illuminated lens No. 2 and its iris, are imaged by the objective upon the specimen when the objective is at proper focus. By closing the iris in front of the aspheric condenser, the aperture of the light cone entering the objective is reduced similarly to that accomplished on some outfits by placing an iris diaphragm on the side of the vertical illuminator but in a better location as it is in the back focus of the objective. This reduction of the light cone below the aperture of the objective gives decreased illumination, and decreases the numerical aperture with attending results, for example, less resolving power, greater depth of focus and greater apparent flatness. Full apertures are obtained with iris opening of 16 millimeters for 4-millimeter objectives and 18 millimeters for 16 and 32-millimeter objectives.

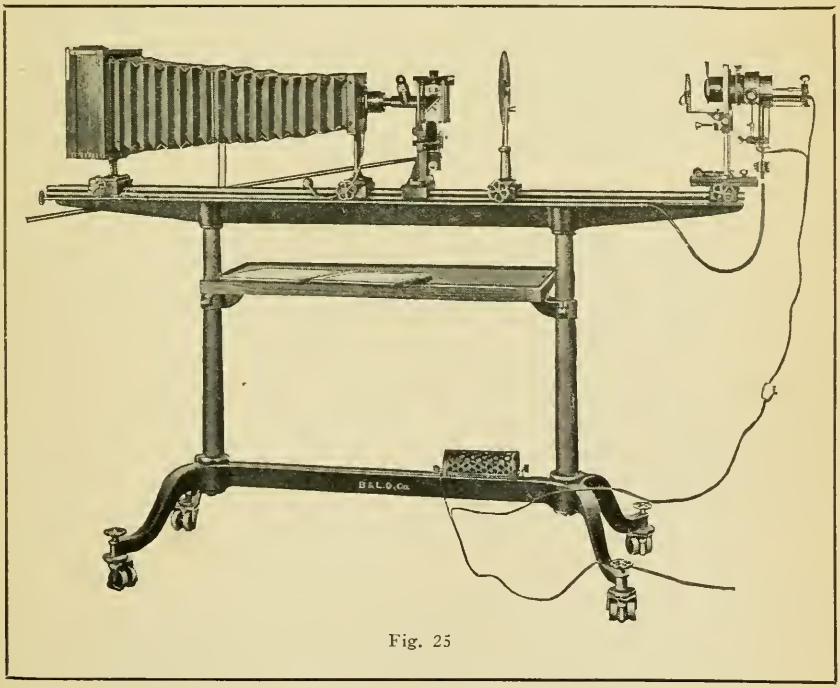


Fig. 25

Fig. 25—GSA type camera used with large inverted microscope IL

The iris of the supplementary lens No. 2 being imaged on the specimen, when closed reduces the size of the illuminated spot upon the specimen, reducing the visible field. By just opening this diaphragm enough to clear the field of view, unnecessary rays are cut off, which rays if they fall on tubes of the objective, illuminator, etc., might cause a flare. The light returning from the specimen after passing through the objective and vertical illuminator, is reflected by a stellite mirror to the eyepiece. The use of a metal mirror reduces all chance of flare which might come from the plane surface of a glass prism.

With the appliances just mentioned, the illumination scheme for metallurgical work as described in the Zeiss circular, Micro No. 89, may be obtained, although the adjustments are somewhat different. It should be noted that in both visual and photographic work decrease in illumination should be accomplished by filters and not by diaphragms which reduce aperture, unless reduction of aperture is desired to secure certain results. Later on will be shown how these optical parts are adjusted to secure the best results as regards centering.

Another method of illumination used on some outfits consists in a supplementary condenser and iris, attached to a side tube, and permanently mounted upon the vertical illuminator. Good work has been done with this form, but this style presupposes that the supplementary lens and iris are correctly centered for each and every objective, which is not always the case. Furthermore, the centering of the illumination is more difficult than is the case where the lens and iris are adjustable. If a ground glass is used in front of the illuminant, the lack of centering is less apparent, but the illumination is greatly reduced and the exposure increased. In experimenting with both methods the adjustable lens and iris has been found to give the best all around results. Some applications of the small side tube on the vertical illuminator reduce the available aperture so that one can best tell how much aperture is used by observing the back lens of objective with a pinhole cap. In some outfits of this kind it has been impossible to obtain fully illuminated objectives.

Any ordinary microscope with proper optics may be used in the examination of metals but it is in this case either necessary to mount each and every specimen at a fixed height to avoid readjustment of the illumination or to have an illuminating device attached to the vertical illuminator, such as the Tassin, shown in Fig. 14. This entire stand was made for the late Dr. Tassin, of the United States navy yard, for examining polished spots on large castings. It is somewhat like the workshop microscopes of Swift and Watson, after the design of Mr. Stead. The illuminating device consists of a 15-Watt incandescent lamp, operating on the regular 110-volt circuit, and two condensers. As can be seen from the illustration, it is attached to the illuminator and moves with it and the optical parts. It may be applied to any ordinary microscope and the results obtained are good for magnifications up to about 200 diameters in visual work. It may also be used in photography for about 100 magnifications, but of course cannot compare with the better instruments and cameras.

The general form of stand for metallurgical work, however, is one in which the stage and specimen are movable by rack and pinion, as by this method varying thicknesses of specimen can be accommodated without deranging the illuminating system. Instruments of this type require the mount-

ing of the specimen in wax or other form of holder. In the case of steel specimens a Sauveur magnetic holder may be used, the specimen being held from the under side by magnetism.

Fig. 15 shows a typical form of metallurgical microscope for student use. This type of microscope was suggested by Professor Sauveur many years ago. Fig. 16 shows a similar stand with more delicate fine adjustment and a revolving stage with centering screws. To this stand may be attached a mechanical stage of the form shown in Fig. 17 This microscope was also designed by Professor Sauveur. It differs from the preceding model in that it has a side tube for connecting to the camera, so that visual observations can be made without disconnecting or moving the camera, the only operation necessary being the withdrawal of the side tube, with its prism, from the optical axis when making visual observation or in adjusting the light and the specimen.

Many workers prefer a stand of the inverted type, that is, one in which the stage is above, instead of below the objective, and in which it is necessary to prepare one surface only, the polished face being placed face down upon the stage over the objective. The inverted form of microscope is credited to Le Chatelier in the year 1897. It has been made in a variety of forms, first by Pellin of Paris, later by Dujardin & Co. of Paris. Other models have been made by Leitz of Germany and Reichert of Austria. A model is said to have been made by Zeiss of Germany, but never appeared on the market.

Fig. 18 shows the large inverted stand of the Bausch & Lomb Optical Co. and embodies all the desirable features of a metallurgical microscope. In this model all parts are of heavy construction and the pieces are limited to the least number to insure rigidity. The rack and pinion are massive and the pinion is operated by a worm which, in addition to giving a smooth slow movement, acts as a locking device and prevents the stage from falling, no matter how large and heavy the specimen may be. The fine adjustment is of the side lever type which automatically compensates for wear. Both adjustments, the rack and pinion and the fine adjustment, move the stage and specimen, the optical parts, including the vertical illuminator, being fixed at all times and when once centered, no change occurs during focusing. The reflector below the vertical illuminator is of stellite, a hard noncorrosive metal. The mechanical stage has all adjustments from below and clamps are provided for holding small specimens and thin sheets of metal under observation.

A modification of this stand is now in use in the laboratories of Dr. Merica of the International Nickel Co. and the American Brass Co. In this modification, shown in Fig. 19, the stage is provided with leveling screws, which makes possible the location of any crystal face perpendicular to the optical axis of the microscope even though this face may not be parallel to the general surface of the specimen.

Other types of metallurgical microscopes which should be mentioned are those of Martens, made by Zeiss, and the Rosenhain microscope, made by Beck. The Marten's stand is of horizontal type, provided with movable stage and is in general form similar to the stands at first described. The specimen must be mounted so as to retain the polished surface in a vertical position. The illuminating apparatus is placed at right angles to the axis of the micro-

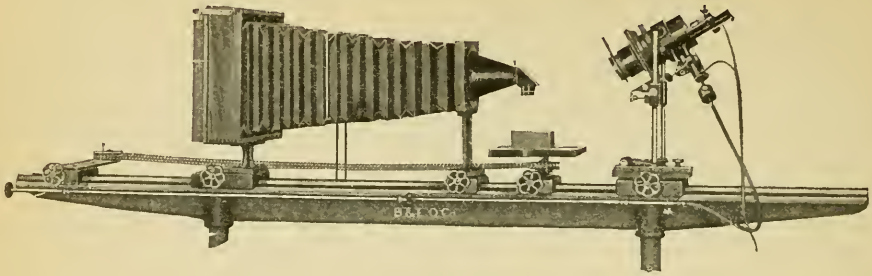


Fig. 26

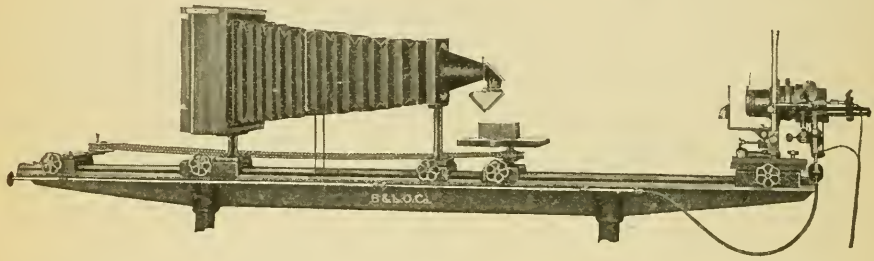


Fig. 27

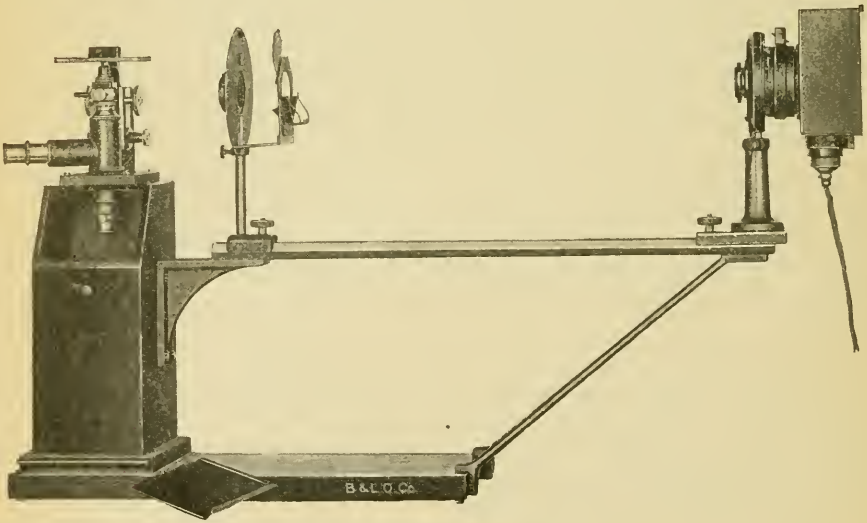


Fig. 28

Fig. 26—Arranged for attaching low-power photographic lenses to camera and device for holding and focusing the specimen. Fig. 27—Plate glass holders supplied for vertical illumination with low-power lenses. Fig. 28—Small metallographic outfit for student use

scope. The Rosenhain is an enlarged and heavy form of usual type and has its vertical illuminator built into the tube.

Suitable illuminant for metallography creates considerable discussion. The direct-current arc with small carbons is no doubt the best illuminant for intensity when used with a good condenser lens. In Fig. 20 is illustrated an illuminant with arc lamp. The condenser in this illuminant is made with special nonspherical curves gathering a cone of about 60 degrees from the arc and forming the rays from all zones into an image in approximately one plane. The ordinary spherical condenser will not do this, as it has what is known as spherical aberration, and the various zones of the lens focus at various planes. The condenser, however, is not chromatically corrected, nor is this necessary in general work. Centering screws are provided to bring the arc in center with the condenser and this is necessary that the condenser may be evenly illuminated, because as shown in a previous illustration, this illuminated lens is projected into the back focus of objective and must illuminate it evenly.

In front of the condenser is an iris diaphragm, which serves to reduce the illumination without reducing the field of view as previously described. A holder is also provided for ray filters and the lamp may be adjusted in both vertical and horizontal directions. It may also be tilted to an angle as much as 45 degrees and used to illuminate large rough specimens or deep etchings in gross photography. A later illustration will show this adjustment. The carbons used in this lamp on direct current are a 5-millimeter horizontal or positive carbon and a 4 millimeter vertical or negative, and it is necessary to see that the positive pole of the current from supply wires is so connected. This may be determined by noting which carbon is brighter. The brighter one should be the horizontal carbon. The positive carbon should heat uniformly over the entire end, and will provided proper voltage is used. It is important that the rheostat, which must be used with the arc be made for the voltage of the supply wire so as to produce 60 volts across the arc. Some users have had trouble in obtaining even illumination because they used a rheostat intended for 110 volts on a current of 100 volts. The lower voltage causes the carbon to heat only on part of the end. When imaged on the supplementary lens only part of the lens is illuminated and, therefore, only part of the specimen is illuminated. While the larger carbons burn longer without adjustment they do not heat evenly, although a 6-millimeter positive and a 5-millimeter negative are fairly good. In an emergency a ground glass may be used to diffuse uneven illumination if it is due to above causes.

Alternating-current arcs are not very satisfactory, as a rule, and yet many are forced to use alternating current. It would be much better to install a rectifier or motor-generator set. If, however, nothing else is available, it may be used with a 5-millimeter horizontal and an 8-millimeter vertical carbon, but the results will not compare with those obtained with direct current. Many users have had success with a 6-volt Mazda lamp of 24 watts capacity on alternating current and one of the metallurgists in the Dow Chemical Co., Midland, Mich., who has made photographs with this lamp at all magnifications, claims results are satisfactory. A better lamp now available for alternating current is the Pointolite to be described later

Fig. 21 shows the adaptation of this 6-volt lamp to the same stand as the arc and one of these lamps should be a part of every outfit for visual work. Critical illumination cannot be obtained, for if the lamp is focused upon the

specimen, the coils will be visible. This can be overcome, however, by so adjusting the aspheric condenser as to diffuse the image of the filament. A higher power incandescent lamp recently has been adapted to this work. It is of 6 volts, 108 watts capacity and gives a brighter and more compact light than the 24-watt. It may be adapted to the same stand.

Another lamp which is now upon the market is known as the Pointolite and probably will solve many of the problems of illumination in photomicrography. The lamp consists of a spherical bulb in which is mounted a very small ball of tungsten. It approaches the ideal point source. By means of a special resistance and ionizing rod, this ball becomes incandescent and gives a fine light. This lamp is now made to interchange with the arc on the standard previously shown, and while not as bright as the arc, it

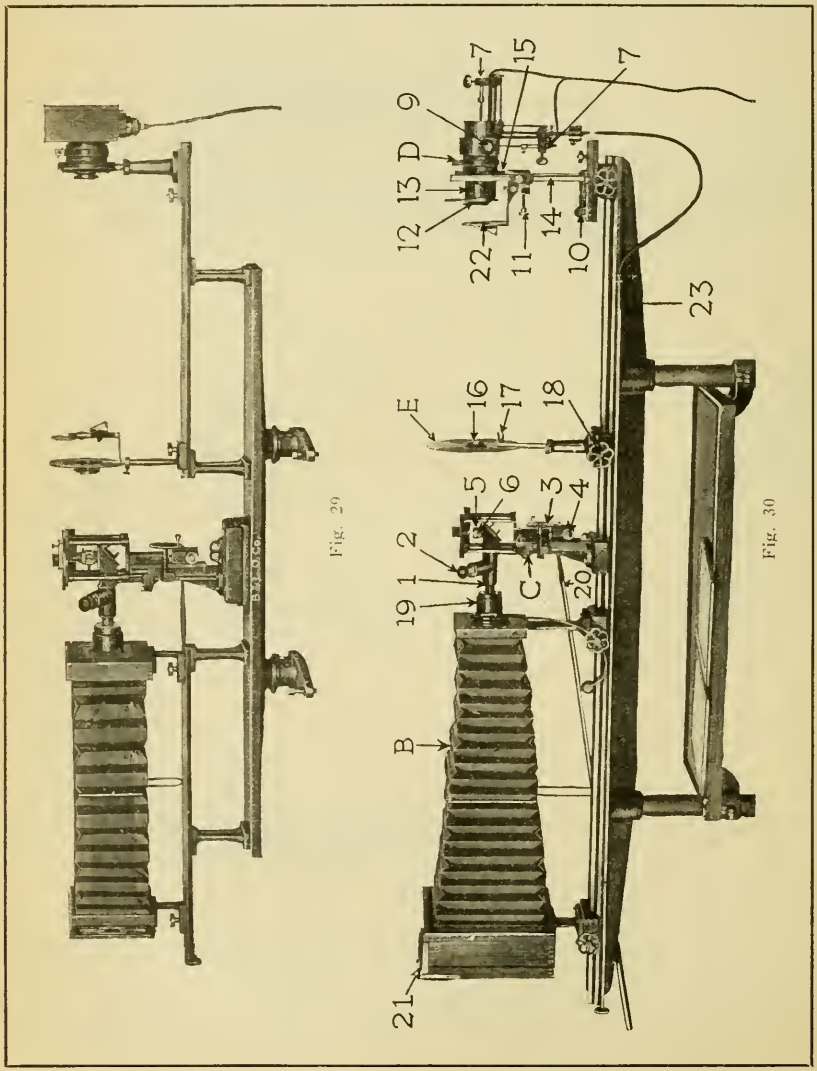


Fig. 29—Outfit having refinements of large inverted microscope but without appliances carried by larger camera. Fig. 30—Metallographic outfit with parts numbered for reference

gives enough illumination to focus on the ground glass under most conditions and has the advantage of being uniform, steady and automatic. The aspheric condenser magnifies the tungsten ball enough to cover the supplementary lens and, of course, critical illumination can be obtained. While this lamp was originally designed for direct current, a rectifier can now be obtained for use on alternating current. A number of photographs with this light at both high and low magnifications shows it well suited to photomicrography. The spectrum is from 410 to 710. It is hoped that this lamp shortly will be made in this country. The advantage of a stand to which all types of illuminants can be attached is obvious.

The cameras and supports available for this work probably are as great in variety as the microscopes. A few types will be referred to, all of which embody supports to carry an illumination system of the type described. Fig. 22 shows a simple type of vertical camera which has been in use for a number of years. It differs from the ordinary, in that the camera and all accessories are mounted on a single base board to which they can be clamped after adjustment. It is annoying in this work to have a number of loose parts which are readily disturbed. Fig. 23 shows a low form of stand with vertical camera. When resting on the floor the ground glass is at a convenient height for observation. The camera may be swung to one side when making adjustments of the specimen and illumination.

Fig. 24 shows a type especially designed after suggestions of Professor Sauveur for use with the side tube microscope. As stated, when referring to the microscope, the side tube is withdrawn for visual observation and again pushed into the path of light when making photographs. The light-tight connector between camera and microscope is so made that neither camera nor microscope need be moved in making the adjustment from visual to photographic use. All the camera supports described are made with either 4 x 5 or 5 x 7-inch cameras. Fig. 25 shows a camera known as the GSA type and is used with large inverted microscope IL. The camera takes all sizes of plates from 3 x 4 to 8 x 10 inches by means of kits in the plate holders. The larger sizes are useful in gross photography with low magnifications or reductions. Devices for feeding the arc lamp and for adjusting the fine adjustment from a position behind the ground glass are supplied. The arc may also be adjusted while making visual observations, and an adjustable mirror is furnished so that the arc can be observed from all positions. This makes the use of a hand-feed arc convenient. Two focusing screens are supplied, the ground glass for giving a general view of the entire image and a clear glass for fine focusing with focusing glass. These are set at right angles to the axis of the camera and images are formed direct and not by reflection. A plate holder of book form is supplied, and trial exposure may be made by withdrawing dark slide, giving the plate an exposure of 15 seconds; replacing slide 1 inch at a time, giving each succeeding inch 15 seconds, so that the final exposure on a 5-inch plate would be 75 seconds, 60 seconds, 45 seconds, 30 seconds and 15 seconds for the various parts.

After some experience it is easy to judge the correct exposure for a given class of objects. Special appliances are made to meet the requirements of various workers. This camera is also supplied in low form to place on a laboratory bench. In using high powers with all outfits, time must be given for all parts to settle in position, and then make final adjustment of focus. The microscope should be focused, then after a time equal to exposure, the

image should be examined. If still in focus the exposure may be made. If out of focus this operation should be repeated, the exposure postponed until all adjustments have come to rest.

Fig. 26 shows an arrangement for attaching low-power photographic lenses, of the 32, 48 and 72-millimeter foci, to camera, and special device for holding and focusing the specimen. The focusing is done by chain movement from rear of camera while observing the ground glass. It is intended for the photography of fractures etc., and was first made for Dr. Merica of the International Nickel Co. This also shows the illuminant as used for oblique illumination. Plane glass holders were also supplied for vertical illumination with these low power lenses as shown in Fig. 27. A recent paper of the Bureau of Standards shows a number of low power photographs. They were made both with vertical illumination and with incident

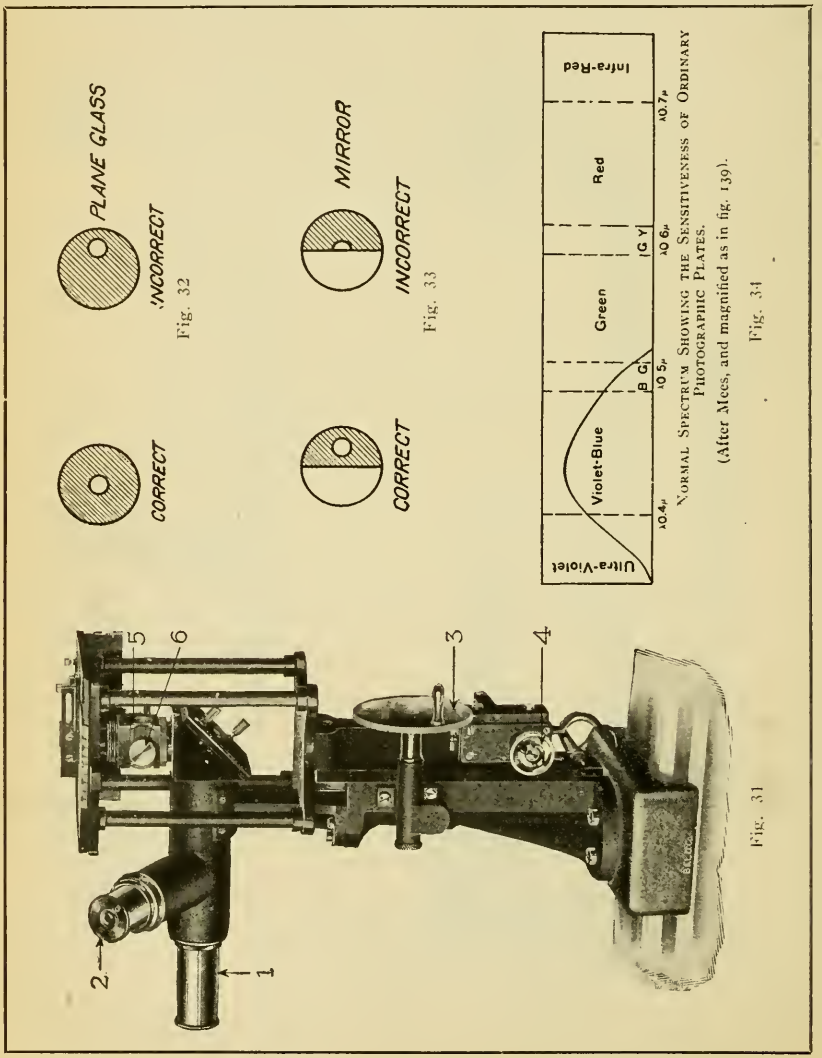


Fig. 31—Close view of microscope and plane glass with vertical illuminator set at 45 degrees. Fig. 32—Method of adusting light spot with plane glass. Fig. 33—Method of adjusting mirror illuminator. Fig. 34—Sensitive region of the ordinary photographic plate

light. Some specimens need to be coated or immersed in alcohol or water to bring out details.

Two new outfits have just appeared upon the market and have not as heretofore been described. The first shown in Fig. 28 is a small outfit for student use and for industrial plants where only a small amount of work at low and medium powers is required. The microscope is of the inverted type and is mounted over the camera. The specimen is examined by means of a side tube which, with its prism may be withdrawn from the optical axis permitting the image to fall upon the plate in the camera. While the image may be focused upon an opaque screen in the camera it is possible to so adjust the camera eyepiece that the image is sharp upon the plate when focused for visual observation. The illuminant may be either the Pointolite or the 6-volt, 108-watt Mazda lamp. The mountings for lamp and the condensers are of much simpler form than in the previous outfits but will give satisfactory results in magnifications from 50 to 400.

The second outfit shown in Fig. 29 has been designed for those who desire the refinements of the large inverted microscope but do not require so large a camera as the 8 x 10-inch or the appliances which this outfit carries. The outfit is solid and gives fine results in photography. The illuminant is of simple form and may be fitted with either the Pointolite or the 6-volt, 108-watt lamp. The condenser is 1½ inches in diameter. The filter holder is mounted upon the supplementary lens stand as is also a simple shutter for making exposures. The microscope is the regular large inverted type and operates in the same manner as previously described. This outfit covers the same range as the usual type of imported apparatus and is lower in price than the large outfit.

Some of the difficulties in the use of metallographic equipment are due to improper adjustment, because it is often found on examining an outfit, that it is not properly centered, or the parts are not in the proper relation to each other. As the large inverted type is now widely used the method of adjustment will be described although these same adjustments apply equally well to smaller outfits fitted with same devices, and instructions may be secured from the makers. One of the main points is the centering and focusing of the illuminating pencil or cone of light. If this is incorrect, good results cannot be obtained. In Fig. 30 the various parts have been numbered for easy reference.

The microscope, *C*, should be 35 inches from the lamp, *D*, so as to obtain an arc image of sufficient size to cover the field, that is, the area of the supplementary lens. If this is not evenly illuminated the field of the objective will not be evenly illuminated. The center of the lamp should be on the same center as the opening of the vertical illuminator, No. 5, and the vertical rods are now graduated to show this position. For preliminary adjustment the supplementary lens should be removed from its standard, and the aspheric lens, No. 13, adjusted so as to give an arc image at a point about 26 inches from the lamp. Then one should close iris, No. 12, in front of arc condenser to a small opening, say ¼ inch. It is assumed that the objective, say 16 millimeters is in position on the vertical illuminator at No. 5.

Fig. 31 shows the microscope closer and the plane glass, No. 6, of the vertical illuminator set at about 45 degrees. Place a highly polished unetched specimen on stage face down, focus objective, and while observing in the eyepiece bring the small spot of light to the center of the field. The

spot should appear as the one in Fig. 32 marked correct. If it is off center, the vertical illuminator should be adjusted either by knob of plane glass, No. 6, or by rotating the illuminator upon the vertical axis until the spot is centrally located.

Going back to Fig. 30 focus the objective roughly and remove eyepiece, No. 2. Place over the eyepiece tube a pin hole diaphragm, for centering the eye with tube. Place supplementary lens, *E*, in position about 6 inches to right of microscope and while observing through pin hole cap, adjust this condenser until the bright spot is in center, as just shown. Then replace eyepiece and close iris, No. 16, of supplementary lens. If the iris is not sharply defined, slide the supplementary lens on its base, No. 18, to or from the microscope until the blades of iris diaphragm can be distinctly seen in the field, when objective is in focus. In making these last observations, the smoked glass cap should be used over the eyepiece. The image of this iris should be concentric with diaphragm of the eyepiece and will be if set-up has been correctly made.

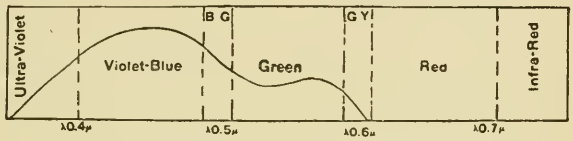
If the arc is now focused on the supplementary lens, the light condition should be as shown as in Fig. 13. Referring to Fig. 31, the arc is nearly focused on supplementary lens, No. 2, by lens, No. 1. Lens and iris, No. 1, are focused at back of objective by lens, No. 2. Arc, lens and iris No. 2, are focused on specimen by the objective. This gives critical illumination. When these results are obtained good images are secured. After a little practice it is not difficult to set up the apparatus in the manner described. Some users introduce a ground glass in front of the arc. This diffuses the light and while giving even illumination, it does not give critical illumination as previously described, but is preferred by some for lower powers and is even recommended by some workers.

In adjusting the mirror illuminator or if a prism illuminator is used the same conditions prevail. The spot of light is to be centered in the field as before and the supplementary lens then placed in position and the location of the light pencil adjusted as shown in Fig. 33. In this case it will be noticed that in the correct position the circle of light is located in the middle of the hemisphere and not centrally with the optical axis. The mirror illuminator is excellent for projecting with low powers. A little practice will enable one quickly to make these adjustments and the results will amply repay for the time spent. The elimination of vibration is one of the difficult problems that most metallurgists have to overcome. No matter how rigid the apparatus, short sharp blows will produce vibrations which make it impossible to make good photomicrographs. There are a number of different devices in use ranging from simple to more elaborate appliances. Each user seems satisfied with his particular device. Probably the simplest and easiest to install consists of two planks, of a size suitable to hold the entire apparatus, and between them two inflated 3½-inch inner tubes or two circles of tennis balls.

Another device much in use consists of a platform suspended from the ceiling, some consisting of simple chains or ropes, others of springs arranged with oil dampers below platform to check the spring movement. Another device designed by Mr. Pafenbach of the Simonds Steel Co., Lockport, N. Y., consists of a submerged platform level with the floor, but suspended upon springs held by angle pieces projecting downward from cross beams, also level with the floor. It seems that each one might best provide such means as are necessary in his particular location, but vibration if it exists,

should be eliminated. Vibration can be detected easily by observing the reflections from a small dish of mercury set upon the apparatus.

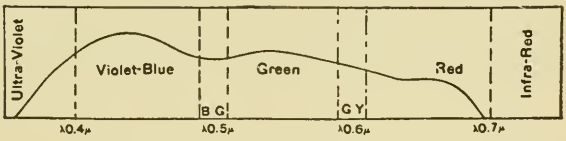
A focusing glass is a desirable addition, and almost necessary if one expects to obtain a sharp image upon the photographic plate, especially in high magnifications. As to the proper color of filter to use in metallography there seems to be some differences of opinion, no doubt due to differences in plates, illuminants, objectives and specimens used by different workers. Different colors have been experimented with and it has been found that on iron and steel specimens a combination of green and yellow dominant wave length of 5500 Augstrom give the best results. Augstrom unit equals one ten millionth of a millimeter. Often the appearance of the image upon



NORMAL SPECTRUM SHOWING THE SENSITIVENESS OF ORTHOCHROMATIC OR ISOCHROMATIC PLATES.

(After Mees; magnification as in fig. 139).

Fig. 35



NORMAL SPECTRUM SHOWING THE SENSITIVENESS OF PANCHROMATIC PLATES.

(After Mees; magnification as in fig. 139).

Fig. 36

Fig. 35—Sensitive region of orthochromatic or isochromatic plates. Fig. 36—Sensitive regions of panchromatic plate for a wide range of the spectrum

the ground glass is made the basis of the proper filter to secure contrast desired but suitable plates must be used to record such an image. Much difficulty is found in obtaining solid glass filters that will give the color desired, so it becomes necessary to use the glass mounted, gelatine stained variety. In the matter of plates one must select a plate suitable to the work and filter used.

Fig. 34 shows the sensitive region of the ordinary plate and if filters are used which transmit only green and yellow with very little blue the exposure will be very long and the results not satisfactory. Fig. 35 shows the sensitive region of the orthochromatic or isochromatic plates and if filters are used such as the B & G Wratten transmitting wave lengths around 5500, this type of plate gives good results. The slower orthochromatic plates have a finer grain and are therefore best for photomicrographic work. Such plates as the Stanley Commercial or the Cramer Slow Iso will give good results. If heat tinted specimens are used and there is much variation in colors all of which one may wish to record, then the panchromatic plate should be

used. Fig. 36 shows that these plates are sensitive to a wide range of the spectrum.

The many factors involved, such as objectives, aperture, magnification, illuminant, filter, etc., make the keeping of records almost imperative. A method of standardizing a photomicrographic outfit has been described by Prof. Alexander Petrunkevitch of Yale University in the Anatomical Record, Vol. 19, No. 5, October, 1920. While his article refers particularly to transparent photography, the same rules can be applied, namely, to determine the best location for each and every part of the apparatus, diaphragm apertures for different objectives, ray filters, plates, etc., and after establishing such record, one may make a picture of a given kind of object in the minimum amount of time and be practically sure of the result without recourse to cut and try methods every time a picture is to be made.

While it is not the purpose of this discussion to talk on the subject of metal, reference should be made to the care necessary in preparing specimens, if good results are to be obtained. The surface of the polished specimen must be flat. Any rocking on the grinding or polishing wheel will produce a cylindrical surface and the field in the microscope will have a band in focus while both sides may be out of focus. We have seen such specimens and had such complaints. Also, the etching must be done properly to produce the contrast necessary to show the structure desired. Light etching has been found to give the best results. It is well again to emphasize the necessity of keeping all parts of the apparatus clean, not only all lenses, but all bearing surfaces. The apparatus should be protected with a rubber cloth covering when not in use, and the metal slide should have a slight coating of vaseline once in a while. The instrument should be placed, if possible, where it is not exposed to the fumes of the chemical laboratory.

EFFECT OF TUNGSTEN CONTENT ON THE SPECIFIC GRAVITY OF HIGH SPEED STEEL

By Arthur S. Townsend

ALTHOUGH it has long been known that high speed steel has a higher specific gravity than carbon steel, a search for authoritative figures on this subject has failed to disclose any complete data. In fact not many figures of any kind could be found. Several of the catalogs of the different tool steel manufacturers mention the fact that high speed steel is heavier than carbon—from 7½ to 15 per cent heavier according to varying estimates. One catalog states that "while the specific gravity of ordinary tool steel is 7.85, that of high speed steel varies from 8.45 to 8.75, depending on the percentage of chromium and tungsten present. Edwards and Kikkawa[1] and Scott[2] give specific gravity determinations on high speed steels, but make no comparisons between steels of different chemical composition.

The reason for the higher specific gravity of these steels is obvious when the specific gravities of the various elements which are used in their manufacture are considered. Tungsten, which is generally present in larger amount than any other element except iron, is one of the heaviest of the chemical elements and the addition of from 10 to 25 per cent of tungsten, therefore, is responsible chiefly for the increase in specific gravity. It is natural to assume that the specific gravity of a steel increases directly as the percentage of metals heavier than iron is increased and conversely that it decreases directly as the percentage of metals lighter than iron is increased. In other words the more there is of an element such as tungsten, the heavier the steel and the more there is of an element like vanadium, the lighter the steel. Table I shows the specific gravities of the various elements used in steel. Additions of carbon, silicon, vanadium, chromium or manganese may be expected to decrease the specific gravity of steel while additions of any of the elements listed after iron should have the opposite effect. Uranium it may be noted is almost as heavy as tungsten, but uranium is only rarely present in steels and then usually only in small amounts.

Observations made in the writer's laboratory from time to time tended to establish the general rule for annealed steels that the higher the tungsten content the higher the specific gravity. A 13 per cent tungsten steel, for example, had a specific gravity of 8.48, while an 18 per cent steel had a specific gravity of 8.70. These experiments together with the theoretical considerations mentioned above suggested that the percentage of tungsten was the principal factor affecting the specific gravity. A systematic investigation was then begun with the object of determining just how close a relation existed between them. The figures which are to follow indicate clearly that the specific gravity of annealed high speed steels increases in direct proportion with the increase in tungsten content, other elements being held constant. The relation between the two is so close and the effect of tungsten content on the specific gravity is so much greater than the effect of any other variable that it has even been found possible to substitute specific gravity

[1] Edwards and Kikkawa. "The Effect of Chromium and Tungsten Upon the Hardening and Tempering of High Speed Tool Steel." Journal of the Iron and Steel Institute, 1915, No. 2, p. 26.

[2] Scott, Howard. "The Relation of the High Temperature Treatment of High Speed Steel to Secondary Hardening and Red Hardness," Scientific Paper of the Bureau of Standards, No. 395, Sept. 16, 1920, p. 528.

A paper presented by title at the Indianapolis Convention. The author, Arthur S. Townsend, is chief chemist, Cleveland Twist Drill Co., Cleveland.

tests for chemical analysis in making tungsten determinations where a high degree of accuracy is not required. A new method for determining tungsten content thus becomes available.

The steels selected for examination were all annealed samples. There were 31 samples of steel in the first collection tested and all of these were carefully analyzed. Three were plain carbon steels, one a carbon steel with 0.46 per cent chromium, one a "tungstenless" high speed steel, two were low tungsten steels and the other 24 were high speed steels with tungsten ranging from 10 to 21 per cent.

Table II gives the percentage of tungsten and the specific gravity found and confirms the general rule given above, although a few slight exceptions may be noted. It also gives the chemical analysis of the samples, the duplicate specific gravity determinations showing how close an agreement was obtained by the method used, and the approximate weights of the samples.

Table I

Specific Gravities of Various Elements Used in Steel*

Element	Specific gravity	Element	Specific gravity
Carbon	1.75-2.10	Cobalt	8.718
Silicon	2.00-2.50	Nickel	8.6 -8.93
Vanadium	6.025	Copper	8.91-8.96
Chromium	6.92	Molybdenum	10.281
Manganese	7.42	Uranium	18.685
Iron	7.85-7.88	Tungsten	18.77

*From Van Nostrand's Chemical Annual.

This preliminary work indicated that the relation between specific gravity and tungsten content was most constant among steels of the same general type. This, of coursse, was to be expected as a number of variables which affect specific gravity are practically eliminated if the steels are all of a common type. It will be noted that 16 of the samples are of the usual type of high speed steel with carbon 0.55-0.81 per cent; chromium 3-4 per cent; vanadium 0.71-1.10 per cent and tungsten 16.5-21 per cent. These sixteen samples and others belonging to the same class were then selected for further study, the idea being that with carbon, chromium and vanadium nearly the same in all the samples, the effect of the tungsten would be ascertained more readily. The results of the subsequent experiments were encouraging and a method was eventually worked out which makes possible the determination of the approximate percentage of tungsten in a sample, the specific gravity alone being known.

A sample weighing about 30 grams is polished roughly to remove scale and "bark" so that a uniform tungsten content is assured. The piece is first weighed in air, then suspended by a fine wire in distilled water and weighed again. It is essential that all bubbles of air be removed from the surface of the piece before taking the weight in water, the easiest way to accomplish this being to dip the piece in alcohol before suspending it in the water. All except a negligible amount of alcohol can be drained off. The weight of the fine wire is deducted and the net weight of the piece in water is subtracted from the weight in air. The specific gravity is then calculated in the usual way. The calculations may be shortened by using a table of logarithms.

An example of an actual determination is given in order to show the simplicity of the calculations.

A—weight of sample in air .....=29.064 grams
B—weight of sample and wire in water .....=25.815 grams
C—weight of wire .....= 0.080 grams

D—weight of sample only in water ....$(B\text{-}C)$=25.735 grams
Subtracting D from A:.....A=29.064 grams
D=25.735 grams

$A\text{-}D=E=$ 3.329 grams

we get E, the loss in weight, representing the weight of the water displaced.

Or using logarithms,

log A=1.46336
log E=0.52231

Log A—log E=log X= 0.94105
and X=8.731

Referring to Table III we find a specific gravity of 8.73 equivalent to 18.57 per cent tungsten.

A single determination including the calculations can easily be made in 15 minutes, after the specimen has been cut off and polished. The method as adopted was purposely made quite rapid and simple so that it could be used in a practical way for checking tungsten determinations. For this reason, no attention was paid to temperature, atmospheric pressure or similar refinements which would be necessary if the highest accuracy were desired.

Work was done to show that the errors inherent in the determination as performed would not make a difference of more than 0.12 per cent tungsten. If the errors in weighing should total 0.002 grams, assuming that a 30-gram sample is used, the error would amount to only 0.12 per cent tungsten and it is, of course, quite possible to reduce the errors in weighing to less than that.

Much larger errors, however, are introduced due to the segregation or other inequalities in the composition of the samples themselves. Experience with the method seems to indicate that the chief variables which affect the specific gravity beside the tungsten are the percentages of chromium, vanadium, and carbon, the presence of slag or other impurities, presence of microscopic cavities, and density of the steel due to previous rolling or heat treatment. The presence of slag will no doubt cause a marked decrease in specific gravity. The low value obtained for sample No. 9, Table II, may be explained in this way. The presence of slag in this sample is indicated by the high silicon and was confirmed by microscopic examination.

Now if we are able to assume or can show that the carbon, chromium and vanadium are within reasonably well defined limits and that slag or other impurities are present only in extremely small quantities, the variables which cause erratic or unreliable results practically are eliminated. With such samples, it is believed that this method will give results which are accurate to within plus or minus 0.3 per cent. That is, if a sample actually contains 17.50 per cent tungsten, the specific gravity determination should show that it has between 17.20 and 17.80 per cent.

In order to test the method, samples of steel which had never been

Table II

Specific Gravity and Tungsten Content of High Speed Steel

Sample	Specific gravity			Tungsten	Carbon	Chromium	Vanadium	Manganese	Silicon	Phosphorus	Sulphur	Cobalt	Molybdenum	Uranium	Weight of sample
No.	1	2	Ave.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Grams
1	7.816	7.810	7.813	None	1.32	None	None	0.20	0.59	0.010	0.019	....	....	....	17
2	7.805	7.812	7.809	None	1.15	None	None	0.37	0.59	0.010	0.016	....	....	....	22
3	7.835	7.826	8.831	None	1.36	None	None	0.21	0.20	0.006	0.017	....	....	....	24
4	7.813	7.820	7.817	None	1.17	0.46	None	0.35	0.22	0.022	0.015	....	....	....	14
5	7.877	7.884	7.881	None	0.61	2.28	2.28	0.05	0.14	.....	.....	4.49	5.41	....	38
6	7.877	7.888	7.883	0.85	1.05	0.41	0.25	0.23	0.30	0.023	0.011	....	....	....	27
7	8.011	8.017	8.014	4.34	1.16	0.75	None	0.48	0.41	.....	.....	....	....	....	44
8	8.329	8.309	8.319	10.29	0.37	3.73	0.61	0.28	0.16	.....	.....	None	None	....	33
9	8.210	8.224	8.217	12.24	0.63	4.46	1.70	0.19	2.12	.....	.....	....	....	0.14	30
10	8.516	8.523	8.520	13.53	0.58	2.82	0.30	0.40	0.18	0.031	0.028	....	....	....	27
11	8.468	8.487	8.478	14.30	0.61	3.89	1.37	0.71	0.46	.....	.....	....	....	....	17
12	8.410	8.434	8.422	14.54	0.66	4.65	2.28	0.25	0.47	.....	.....	....	....	....	51
13	8.525	8.537	8.531	15.76	0.72	4.56	1.04	0.12	0.39	.....	.....	....	....	....	31
14	8.625	8.619	8.622	16.47	0.60	3.49	0.89	0.22	0.13	.....	....	....	....	....	23
15	8.626	8.648	8.637	16.82	0.55	3.99	0.86	0.24	0.16	.....	.....	....	....	....	19
16	8.612	8.637	8.625	16.84	0.55	3.42	0.94	0.03	0.33	.....	.....	....	....	....	23
17	8.633	8.636	8.635	17.44	0.62	3.48	0.70	0.30	0.73	.....	.....	....	....	....	26
18	8.684	8.680	8.682	17.47	0.61	3.31	0.89	0.19	0.26	0.024	.....	....	....	....	41
19	8.651	8.628	8.640	17.52	0.66	3.23	0.71	0.36	0.73	.....	.....	....	....	....	24
20	8.691	8.684	8.688	17.64	0.63	3.97	0.84	0.20	0.23	0.040	0.010	....	....	....	46
21	8.656	8.674	8.665	17.68	0.64	3.95	0.93	0.06	0.36	.....	.....	....	....	....	17
22	8.695	8.700	8.698	17.80	0.59	3.04	0.76	0.05	0.51	0.025	.....	....	....	....	42
23	8.686	8.688	8.687	18.21	0.81	3.50	0.90	0.10	0.43	.....	.....	....	....	....	20
24	8.712	8.712	8.712	18.28	0.63	3.86	0.80	0.30	0.23	.....	.....	....	....	....	39
25	8.708	8.700	8.704	18.32	0.68	3.89	1.09	0.17	0.26	.....	.....	....	....	....	28
26	8.728	8.725	8.727	18.42	0.61	3.90	0.74	0.21	0.28	.....	.....	....	....	....	29
27	8.758	8.751	8.755	18.70	0.66	4.87	0.76	0.37	0.35	.....	.....	....	....	....	18
28	8.702	8.711	8.707	18.76	0.67	3.42	0.71	0.26	0.75	.....	.....	....	....	....	23
29	8.776	8.781	8.779	19.17	0.61	4.45	0.82	0.02	0.20	0.017	0.033	2.88	....	....	49
30	8.754	8.760	8.757	19.33	0.64	3.30	0.71	0.17	0.63	.....	.....	....	....	....	27
31	8.810	8.801	8.806	20.90	0.68	3.61	0.74	0.28	0.66	.....	.....	....	....	....	32

analyzed were selected and the tungsten was determined by the specific gravity method. The samples were then analyzed by the usual chemical method and a few of the results obtained are recorded here in order to show the degree of accuracy that may be expected.

Specific gravity method tungsten, per cent	Chemical analysis method tungsten, per cent
18.16	18.01
18.37	17.94
18.37	18.68
19.39	19.57
18.57	18.32
17.14	17.16
16.73	16.88
19.18	19.21

Table III gives the percentage of tungsten corresponding to any given specific gravity for annealed chrome-tungsten-vanadium steel of the general type mentioned above. The values in this table were obtained as follows: The figure 7.82 was adopted as a base, this being the average specific gravity obtained for the carbon steels. The difference between the specific gravity of the high speed sample and 7.82 then represents the increase due to the tungsten in the steel. If this increase be divided by the percentage of tungsten present as shown by chemical analysis, a quotient is obtained which may be called the factor for that particular sample. For instance, given a specific gravity of 8.70 and a tungsten content of 18.21 per cent, the increase is 8.70—7.82 or 0.88. Thus 0.88 divided by 18.21 gives a factor of 0.0483. After a sufficiently large number of determinations had been made these factors were calculated and averaged and the average factor being very close to 0.0490, this was adopted as the factor for all steels of this type. With 7.82 as the base and 0.0490 as the factor, the figures given in Table III are then easily arrived at. For example, 8.68—7.82=0.86 and 0.86 divided by 0.0490=17.55 per cent tungsten.

It should be understood that this table gives approximate or average values, not exact determinations which hold true in every case. Not every

Table III

Specific Gravity Corresponding to Tungsten Content

Specific gravity	Equivalent tungsten per cent	Variation per cent ±	Specific gravity	Equivalent tungsten per cent	Variation per cent ±
8.60	15.92	.30	8.70	17.96	.30
8.61	16.12	.30	8.71	18.16	.30
8.62	16.33	.30	8.72	18.37	.30
8.63	16.53	.30	8.73	18.57	.30
8.64	16.73	.30	8.74	18.78	.30
8.65	16.94	.30	8.75	18.98	.30
8.66	17.14	.30	8.76	19.18	.30
8.67	17.35	.30	8.77	19.39	.30
8.68	17.55	.30	8.78	19.59	.30
8.69	17.76	.30	8.79	19.80	.30
			8.80	20.00	.30

steel with a specific gravity of 8.66, for example, will have exactly 17.14 per cent tungsten, nor will every steel with 17.14 per cent tungsten have a specific gravity of 8.66, but the table is written in this form for the sake of simplicity and convenience and it gives values which are probably very close for steels of this type.

The usefulness of such a table to the analytical chemist in the steel laboratory is obvious. By means of specific gravity determinations, the results of chemical analysis for tungsten may be quickly checked and any large errors are easily detected. This practice leads to greater accuracy in the chemical analysis.

In case the chemical and physical determinations do not agree and both have been carefully checked, the chemist or metallurgist may then feel assured that the bar of steel in question is out of line in some other respect. Possibly the vanadium content is high or low, or the steel contains an unusually large amount of impurities. It may or may not be defective, but at any rate it is different from the regular steel. In this way, specific gravity determinations aid the metallurgist who is desirous of securing and maintaining a supply of uniform material.

Such determinations also give additional information to the research worker who is studying the properties of high speed steel. In connection with other tests such as miscroscopic examination, fractures, hardness tests and chemical analysis, the specific gravity test gives one more item of information and it is the combination of all these tests which gives the complete record of the quality of a steel.

Acknowledgment is made to J. V. Emmons, who suggested to the writer the idea of using specific gravity tests as here outlined, and who also contributed valuable suggestions and criticisms in regard to the work.

DISCUSSION OF THE HARDENING OF STEEL AND OTHER ALLOYS

By Oscar E. Harder

TO DISCUSS the phenomena of hardening of steel and other alloys, with particular emphasis on the important part played by solution and precipitation is the purpose of this paper. It is hoped that it may serve to put into simple language certain explanations which are in keeping with the well understood reactions in related subjects.

Considerable information regarding the mechanism of solution and precipitation can be drawn from the field of chemistry. This information includes the thermal changes accompanying solution and precipitation, the formation and growth of crystals, the supercooling of solutions, the effect of crystal nuclei on the beginning of crystallization, the effect of foreign matter which may accelerate or retard crystallization, the changes in volume due to solution and precipitation, the growth of large crystals at the expense of the small ones, the effect of the ratio of solvent to solute, the increase in the surface tension due to irregular surface, the effect of surface films on the shape of a plastic body, etc.

Probably the most satisfactory method of attacking this problem is to state first of all, in so far as possible, just what takes place in the heating and cooling of steel. Adhering to the observed phenomena and established facts, let us consider an annealed piece of steel containing less than the eutectoid, for example 0.7 per cent of carbon. We may regard this as an alloy of iron and carbon, or, what seems more satisfactory, a binary system—iron-iron carbide. In this annealed product we have two phases present, the pure iron and the carbide of iron.[1] The shape and size of phases observed in this annealed steel will depend upon the exact heat treatment to which it has been subjected. If the annealing has been complete and the rate of cooling very slow we may have all, or nearly all, of the cementite or carbide of iron in the granular form, as shown by Fig. 1. If the rate of cooling is more rapid, then the particles of carbide will be of more irregular shape, have greater surfaces and be of that lamellar form known as pearlite as shown by Fig. 2, or even of that form known as sorbite as shown by Fig 3. While the microconstituents shown in these photomicrographs have been obtained by treatments different from those mentioned above, their appearance is essentially the same.

For this discussion it is desirable to assume a complete decomposition into pure iron and carbide. A calculation of the phases present at ordinary temperatures by means of the inverse lever arm relations about the point 0.7 per cent carbon with the arm extending to the composition of the phases present shows that there would be 10.5 per cent of cementite and 89.5 per cent of ferrite.

$$\text{Ferrite} = (6.68 - 0.7)\,100/6.68$$
$$\text{Cementite} = 0.7 \times 100/6.68$$

1. By phase is meant a mass of material which is chemically and physically homogeneous, but physically distinct and mechanically separable. It should be understood that these terms are relative and that when we say that a phase is physically homogeneous we mean that our present methods of examination do not disclose heterogeneity. Likewise, what we term a phase may in reality be an aggregate, but our present means of examination does not disclose that fact.

A paper presented by title at the Indianapolis Convention. The author, Oscar E. Harder, is associate professor of metallography, University of Minnesota, St. Paul, Minn.

Let us assume that this annealed alloy is heated. As heating progresses a temperature is reached at which a solution of the iron and iron carbide begins. Because of the custom of designating as solvent that phase which is present in larger amount, we may assume that the pure iron is the solvent and the carbide the solute. However, it is probably a case of mutual solubility. The result of this reaction is that these two phases combine to form one phase which is known as a solid solution and which is considered to be essentially similar to ordinary solutions. Therefore, we are not surprised to observe an endothermic reaction due to the heat of solution. This is the well known decalescence point which is observed in heating steel, especially those steels containing a considerable percentage of carbon, and is usually dsignated by the Ac_1 line. It is also generally true that the volume of a solution is less than the sum of the volumes of the solvent and the solute. Therefore, it seems reasonable to expect a decrease in the volume of the steel after this reaction. [2] As this reaction progresses all of the carbide as such disappears. A calculation just above the temperature at which this reaction is completed will show the amounts of the two phases to be about 77.8 per cent of the solid solution and 22.2 per cent of excess pure iron. This calculation assumes a carbon content of 0.9 per cent in eutectoid steel. Here the phase in larger amount is the solid solution and it is considered the solvent and the pure iron will go into solution and as it does so the heat of solution will be taken up. Likewise there should be a decrease in volume as explained above. Having obtained a homogeneous solution we may expect the volume and the heat absorption to vary with the temperature of the mass.

Solutions of this type are referred to as solid solutions because of their lack of fluidity. However, there seems to be no reason for treating them or their properties differently from ordinary solutions. In this particular case it may be assumed that the individual particle to be considered is either the atom or the molecule. Recent work in the field of X-ray analysis favors the atom as the individual particle in metals and alloys. The phenomena of association and dissociation cannot be studied with the same ease that they can in aqueous solutions, but they seem of minor importance in the present discussion. We are primarily interested in the solution of intermetallic compounds and the results obtained by retarding the precipitation of these compounds so that they do not separate, or the separation is delayed to abnormally low temperatures.

By cooling the solid solution discussed above, a temperature will be reached at which it will become supersaturated with reference to one or more of its constituents and there will develop a tendency for it to precipitate. Some of the factors which influence this process are: The tendency to form crystal nuclei; the growth of the crystal nuclei; the effect of foreign substances; the rate of cooling; the shape of the container; the amount of agitation, etc.

As precipitation continues the solution contains less and less of the pure iron and more and more of the carbide.[3] Finally a concentration is reached at which it is supersaturated with respect to both the iron and the carbide and the two precipitate simultaneously. The mechanism of precipitation may be accounted for conveniently by the formation of crystal nuclei which form when a certain minimum number of the particles in solution collect

2. Sauveur, The Metallography and Heat Treatment of Iron and Steel, p. 199.
3. Investigators are not entirely agreed as to whether the carbon in the solid solution is free or combined with iron. However, the precipitate is the carbide.

and arrange themselves according to a space lattice characteristic of that substance. What this minimum number is has not been determined and the size of the crystal which could first be detected would depend upon our means of observation. Thus in ordinary solutions we have the molecules or ions; then that size of particle known as the colloid, which according to Ostwald[4] has a size of between 0.01 *u* and 1 *uu* (1×50^{-5} and 1×10^{-7} centimeters) or a specific surface between 6.10^5 and 6.10^7; true or coarse dispersions; and, finally, the size which may be seen with moderate or no magnification. However, in the case of the steel under discussion the size of the particles after slow cooling is such that they can be seen under magnifications of X1000 or even less.

When crystals separate from a solution there is heat evolved, which amount should correspond exactly to the heat absorbed in solution. So as the precipitation of pure iron begins there should be an evolution of heat and this causes the arrest on the cooling of steel. The magnitude of this arrest depends upon the relative amount of material precipitated. A calculation will show that theoretically 22.2 per cent of the steel by weight will precipitate as pure iron through a temperature range of about 20 degrees Cent. Since this heat effect is rather small, and is distributed over a considerable temperature interval, the arrest is not pronounced nor should that change in volume be great. However, when the solid solution becomes supersaturated with respect to both the iron and the carbide and simultaneous precipitation takes place, the remaining 77.8 per cent of the steel precipitates at a constant temperature. This large evolution of heat produces the well-known recalescence point in high carbon steels, usually indicated as the Ar_1 line. This reaction should also be accompanied by a large change in volume because a solution changes to a solvent and a solute by precipitation.

As is well known the hardening of steel is accomplished by rapid cooling. Let us take a case in which cooling has been so rapid that no precipitation has taken place. Practically this is not possible with plain carbon steels except with very high carbon content. We have retained at ordinary temperatures the solid solution which is now in a metastable[5] condition. There is a certain minimum temperature to which this solution can be cooled before it passes into the instable[6] region, and precipitation may result. The rate of precipitation depends upon a number of factors. Other conditions being fixed, the higher the temperature the more rapidly will precipitation take place. Presumably the size of the particle in solution in the metastable solution is the same as that of the solid solution at the higher temperatures, and the size of the individual particles will be 1 *uu* or less. Now as precipitation takes place there will be an accumulation of these small particles, atoms or molecules, into larger masses which finally grow to such size that they can be seen at moderate magnifications of say X1000. It is obvious, therefore that these particles must pass through all the intermediate sizes from that of the submicroscopic, atom or molecule, to that of the microscopic. This range includes that size of particle generally referred to as the colloid. Referring again to the hardened steel in which there was no precipitation and in which a solid solution was obtained in a metastable condition, the metastable condition may be changed to the instable condition by different methods: 1. Cooling to lower temperatures[7]; 2. heating to higher temperatures[8]; 3. me-

4. Ostwald, Fischer, "Handbook of Colloid Chemistry," p. 33.
5. Findlay, The Phase Rule, pp. 30 and 77.
6. Findlay, loc cit.
7. Hoyt, Metallography, Part II, p. 164.
8. Monypenny, J. Iron & Steel Inst. 101, No. 1, p. 493. Also Andrews, et al, Ibid. p. 601.

chanical treatment[9]. If the instable condition is reached by cooling to a lower temperature then the precipitation would be very slow and presumably after a considerable time the precipitation might still be incomplete. Such solutions should show a decreasing tendency to form crystal nuclei and a decreasing growth of crystals as the concentration decreases. On the other hand, if instability is brought about by heating to higher temperatures the

Fig. 1—Cementite. 0.40 per cent carbon steel quenched from 900 degrees Cent. in water; reheated to 690 degrees Cent. for 21 hours and air cooled. Fig. 2—Pearlitic cast steel of 0.40 per cent carbon. Fig. 3—Sorbitic 0.35 per cent steel, quenched in water from 850 degrees Cent.; reheated to 600 degrees Cent. and air cooled. All specimens etched with picric acid in alcohol and X 1000.

precipitation when once started would be more rapid and therefore go to completion in a shorter time or more nearly reach completion in a given time. The change from the metastable to the instable condition probably accounts for all that really happens in the so-called crystallization of metals under fatigue or vibration. Likewise, it probably accounts for the observed

9. Howe, Proc. A. S. T. M. 17, II, 5-8 (1917). Monypenny, loc cit.

hardening of high manganese steels in such service as crushers and ball mills[10].

Such quenched steels which have been retained in the form of solid solutions at ordinary temperatures are known as austenitic steels and that microconstituent as austenite[11]. It is known that these steels do not show the ordinary arrests when cooled sufficiently rapidly to retain them in the austenitic condition. However, when they are cooled to lower temperatures so that the transformation takes place there is a heat evolution. Also when the transformation is brought about by heating there is observed a heat evolution[12]. Austenitic steel does not show, under our present microscopes, any particles of the iron carbide. While it shows crystals and individual grains on deep etching, it shows neither pure iron nor pure carbide.

If the transformation takes place upon lowering the temperature, or upon heating, there is observed a heat evolution such as might be expected had the transformation taken place upon slow cooling, and the other phenomena which would accompany precipitation are observed. However, if this steel is examined under the miscroscope only a single phase will be observed. At a magnification of one thousand or somewhat more, we are not able to observe any particles of cementite. It seems reasonable, therefore, to assume that precipitation and crystallization have taken place, as indicated by the heat evolution, and that we have, instead of a solid solution, a precipitate of iron carbide in a very finely divided condition, probably the magnitude of the particles being near that which is usually designated as the colloidal particle, and either the pure iron from which the carbide has been precipitated, or possibly a certain amount of the original solid solution from which the precipitation of the carbide is not yet complete. This precipitation results in two phases, or the solvent and solute, which we may expect to occupy a greater volume than the original solution and, therefore, produce the increase in volume frequently observed in hardened steel, and as a consequence, the enormous stresses which in some cases are sufficient to break large cylinders of hardened steel. If the carbide were precipitated in this finely divided condition, it would have a larger surface and a larger volume than it could have with any increase in size of particles.

The conditions mentioned above would seem to account for the properties of martensitic steel, which may be obtained by cooling austenitic steel to very low temperatures, by heating it for a period of time at a low drawing temperature, by stressing austenitic steel, or by cooling it at a less rapid rate than indicated above so that precipitation is retarded but takes place somewhat before it reaches ordinary temperature.

If steel of the type referred to as martensitic steel, is heated to increasingly higher temperatures, it is well known that it becomes softer, stresses are removed, and soon particles of carbide appear which can be distinguished under the microscope. This would seem to be a process of collection of the small particles, probably colloidal, in martensitic steel into larger and larger particles. The mechanism of this growth of particles might be through a dilute solution of the carbide similar to the growth of certain crystals in aqueous solutions where the large crystals increase in size, the small crystals decrease in size and finally disappear, or possibly this growth might take place through the amorphous material surrounding the grain boundaries. As the size of the particles increases the total surface

10. Howe, Proc. A. S. T. M., 17, II, 5-8 (1917).
11. Sauveur, The Metallography and Heat Treatment of Iron and Steel, p. 463.
12. Honda, C. A. 14, p. 3629 (1920) reports the heat of transformation of austenite to martensite to be 4.2 calories for 0.80 per cent carbon steel.

would decrease, and likewise the volume occupied by these particles. These changes would seem to account for the softening of the steel and for the removal of internal stresses.

As this drawing temperature is increased, the particles that first appear are very fine and can hardly be distinguished as separate phases under the microscope, as shown in Fig. 3. Depending somewhat upon the size of these particles and their appearance under the microscope, steels have been classified as troostitic, sorbitic, etc. To take the most extreme case in the growth of these particles, we have granular pearlite which can be obtained by a long-continued drawing process at the temperature just below the lower critical, as shown in Fig. 1. Here the carbide particles collect in large size so that they can be observed and identified at relatively low magnifications. They are rounded and therefore approach the minimum surface and the minimum volume for that size of particle. This results naturally in a very soft form of steel.

Influence of Alloying Elements. The influence of alloying elements seems to be primarily to change the rate of solution and precipitation, and finally the rate of collection of small particles into large ones. It seems that the various properties of alloy steels can be explained with considerable satisfaction from this point of view. Alloying elements may associate themselves with the carbide, with the pure iron, or with both. For example, the chromium and tungsten elements are supposed to be associated principally with the carbide; nickel and manganese, on the other hand, are more inclined to be with the iron. However, in either case this alloying element will influence the rate at which solution will take place on heating an annealed steel. It may make it go into solution at lower temperature, as is the case with nickel and manganese steels, or it may go into solution at higher temperature as in the case of chrome and tungsten steels. Having obtained a perfect solution of these steels, when they are quenched the precipitation takes place more readily or less readily than in a straight carbon steel. Thus the alloying elements in steels are probably more easily understood if they are considered as catalysts which accelerate or retard the rate of solution and precipitation of the carbides.

Hardening of Nonferrous Alloys. Phenomena similar to those discussed above have been observed in the heat treatment of nonferrous alloys. The nonferrous alloy which has attracted most attention, because of the fact that it can be heat treated, is doubtless duralumin[13]. This alloy contains copper about 3½ per cent, manganese 0.5 per cent, magnesium 0.5 per cent, iron and silicon about 0.25 per cent each, and the balance aluminum. Copper and aluminum form an intermetallic compound, $CuAl_2$, which has its maximum solubility at about 540 degrees Cent., which solubility is about 4 per cent copper and decreases to probably 1 per cent at ordinary temperatures. This alloy, as is well known, is heat treated by heating almost to the region of maximum solubility, quenching and then aging. Quenching in this particular case does not seem to retain the alloy in the metastable condition at ordinary temperatures but permits it to go into the instable condition so that precipitation begins and gradually continues at ordinary temperatures. However, there is observed a heat evolution on reheating the quenched alloys to 250 to 275 degrees Cent. according to Merica and his co-workers. This precipitation results in an increase in the hardness and tensile strength. The

13. A comprehensive discussion of the heat treatment of duralumin is contained in Sci. Paper U. S. Bureau of Standards, No. 347, by Merica, Waltenberg and Scott.

rate of precipitation, or aging, at ordinary temperatures is much slower than it is if elevated temperatures are used. Thus having obtained the instable condition, the rate of precipitation is accelerated if an elevated temperature is used, but if too high temperature is used, there is a decrease in strength. Presumably as higher and higher temperatures are used there is first obtained a condition which approaches complete precipitation, which would give the maximum strength for a particular alloy, and then there would result a collection of the fine particles into large ones with a decrease in the surface of the precipitated particles and a decrease in their volume, with the result that there follows a decrease in the hardness of the heat treated alloy and also a decrease in its tensile strength. Apparently that balance between these two reactions which gives the maximum hardness is the condition which has recently been termed "critical dispersion" by Jeffries and Archer.[14] as it appears to the author the maximum hardness should represent maximum precipitation with minimum size of the precipitated particles. There is some evidence to indicate that similar conditions are observed in the case of steel. For example, the writer has had experience with hardened eutectoid steel which showed much greater plasticity immediately after quenching than it did after a draw at temperatures as high as 450 degrees Cent. for a period of one hour. Commercially, the binary alloy of copper and aluminum is not hardened by heat treatment. Instead of that, use is made of an alloy to which has been added small percentages of manganese, magnesium, and in some cases calcium. This more complicated alloy seems to correspond to our alloy steels, and the function of the element, such as manganese, magnesium and calcium, is principally that of a catalyst with reference to the rate of solution and precipitation.

Another illustration of the heat treatment of nonferrous alloys is found in the alloys of magnesium and aluminum. The exact nature of the intermetallic compound formed in the aluminum-rich alloys is not as well established as in the case of the copper-aluminum alloys. Merica, Waltenberg and Freeman[15] concluded that the intermetallic compound was Mg_4Al_3 and determined its solubility in the region between the eutectic point 450 and 300 degrees Cent. They found a homogeneous structure with 12.2 per cent magnesium at 450 degrees Cent., but a duplex structure with 5.9 per cent magnesium after annealing at 300 degrees Cent. This indicates a decrease of over 50 per cent in the solubility through a range of 150 degrees Cent. In a somewhat more recent publication by Hanson and Gayler[16] the authors find about the same solubility at 448 degrees Cent., but a considerably greater solubility at 300 degrees Cent. They also concluded that the intermetallic compound is Al_3Mg_2 instead of Mg_4Al_3. Regardless of which of these is the correct formula for the solute, there seems to be no question but that it is an intermetallic compound dissolved in aluminum. The alloys of this system which are rich in magnesium are also solid solutions and Hanson and Gayler have assigned to the solute the formula Al_2Mg_3. Alloys of this type containing about 8 per cent of aluminum have been developed commercially and respond to heat treatment. In both of these cases complex alloys containing small amounts of metals such as calcium would seem to correspond to alloy steels and presumably increase the effectiveness of heat treatment.

While a general use has been made of the alloying elements in the steel

14. The Slip Interference Theory of the Hardening of Metals, Chem. & Met. Eng. 24, p. 1061 (1921).
15. Scient. Paper, U. S. Bureau Standards, No. 237, p. 113, 1919.
16. J. Inst. Metals, vol. 24, No. 2, p. 201 (1920).

industries, such elements as manganese, nickel, cobalt, chromium, molybdenum, tungsten, vanadium, uranium, having been used, it does not seem that their influence on the rate of precipitation and solution has been sufficiently emphasized. This relation stands out more prominently in the nonferrous metals in which the effect of heat treatment is greatly increased by the presence of a small amount of some of these elements which prevent or retard precipitation on cooling.

In the examples cited, it appears that hardening is obtained by first dissolving an intermetallic compound to produce a solid solution, quenching at such a rate that the compound is retained in the metastable condition, and later carried into the instable condition where precipitation takes place by cooling to lower temperatures or heating; or this same result may be obtained by a quenching at such a rate that the product obtained at ordinary temperature is in the instable condition so that precipitation gradually takes place, resulting in aging at ordinary temperatures or accelerated aging if slightly elevated temperatures are used.

Theories recently advanced by Rosenhain[17] and by Jeffries and Archer[18] with reference to the hardness of metals and alloys, have an interesting bearing on the heat treatment of alloys. The theory advanced by Rosenhain for the hardness of solid solutions seems to apply particularly to increasing hardness of alloys by the introduction of solute atoms into the space-lattices of the solvent. This relation the author states as follows: "The hardening effect of one metal upon another in the form of a solid solution should, to a first approximation, be inversely proportional to its solid solubility." In other words, the hardness in solid solutions is a function of the degree of saturation.

To account for the hardness in heat treated alloys by this theory, it is necessary to have a high degree of saturation. For example, martensitic steel would be a highly saturated solid solution; the change from austenite to martensite need only to involve a change in the degree of saturation. This change in saturation might be due to difference in the solubility of the solute at different temperatures, or to the formation of a new solute, as for example the formation of iron carbide from carbon and iron atoms, which has a markedly different solubility. On the other hand, the theory advanced by Jeffries and Archer seems to apply particularly to the hardening of alloys by a heat treatment in which the maximum hardness is due to a certain "critical dispersion" of precipitated particles. By this theory martensitic steel would be a hetrogeneous system in which the carbide is in the precipitated condition instead of being a solid solution.

If these general principles apply to the hardening of alloys, then we may speculate somewhat as to the future possibilities of the heat treatment of both ferrous and nonferrous alloys. First, it would be necessary to have a condition, or a system, in which there exists a solid solution having a difference in its saturation at different temperatures. The greater this difference in saturation the greater the possible effects of heat treatment. Those systems in which the solute is an intermetallic compound seem to offer the greater opportunities. Quenching would have to be accomplished by heating to a temperature such that the solute would be in solution, and then cooling at such a rate that the solution would be retained at ordinary temperatures with an increase in the saturation, or it would be retained in the instable

17. The Hardness of Solid Solutions, Chem. Met. Eng. 25, p. 243 (1921).
18. Loc cit.

condition so that precipitation would gradually take place. If the desired results cannot be obtained by the avaliable methods of cooling, then the next step would be to find some catalytic agent which would retard, or possibly prevent, the precipitation of the solute.

This idea opens up an unlimited field for investigation. As an illustration, the alloys of aluminum and iron at the present time are supposed to be worthless commercially; however, they form an intermetallic compound and if a catalyst could be found which would make it possible to retain this intermetallic compound in solution at ordinary temperatures and then have it precipitated, an alloy of great commercial value might be obtained. The possible combinations with the metals now available is practically unlimited. Researches along these lines may be expected to give good rewards, both to the researcher and to industry.

THE CARBONIZING OF CAST STEEL PARTS

By William G. Conner

MANY objections are made to the use of carbonized cast steel parts because by construction these parts are porous and dense in spots, causing them to distort or warp in hardening after carbonizing. Many manufacturers claim to get good results by carbonizing and dipping or quenching the castingly directly from the carbonizing pots. This may be good practice for small parts but in carbonizing large gears or clutches, which are very difficult to handle at high temperatures, the author finds it unsatisfactory to try quenching at that period. All parts or pieces should be cooled in pots to atmospheric temperature, in fact slightly above this point will not prove detrimental, except in the case of cold rolled steel which can be carbonized and quenched directly from pots at carbonizing temperature. A nice refined case will be the result.

In packing cast steel the heat treater should use the same method as in carbonizing any other vanadium and alloy steel, using a pot large enough to allow sufficient carbonizing material to be packed between the inside of pot and all work or pieces. The writer finds that a good grade of carbonizer, not too fine, about ¼-inch in size that will pass through ¼-inch mesh screen is satisfactory as too fine a carbonizer becomes so tightly packed that it causes a longer time for heat penetration. These pieces vary greatly in carbon content; from as low as 12 to 15 per cent to as high as 25 to 30 per cent carbon. After this treatment many gear teeth when fractured showed a good deep penetration, 1/16 to 7/64 inch deep, and had a fairly refined case, at least as refined as one could expect with cast steel. Better results are obtained by annealing either before machining or after rough machining to see that the steel is usable.

Some hardeners tabulate their carbonizing furnace time from the moment the pots are entered into the furnace until they are removed, but that method is deceiving. The time should be tabulated from the time the pots and contents reach the desired carbonizing heat. For that reason the furnace is heated up to 1550 or 1600 degrees Fahr. before loading. That is, in the evening after the day's run the pots are all packed and sealed, and the furnace reloaded thus leaving the pots in the hot furnace over night to absorb the heat. By 7 a. m. the pots or pyrometer reading will be 1000 to 1200 degrees Fahr., depending upon the load and amount of heat in the furnace when loaded. This insures an early or much more prompt carbonizing heat throughout the pots and furnace. By 10:30 a. m. the temperature easily reaches 1675 or 1700 degrees Fahr. after which it is readily maintained at a 1700 degrees Fahr. temperature throughout the day or until 5:30 p. m., at which time, after taking out the day's heat to normalize or cool down in pots, another load is ready to be carbonized.

For hardening these large cast steel gears and other parts special tongs have been made which grip the gears well over the teeth or face and in toward the center of gear web or spokes, so as not to interfere with the teeth in any way. By using a rope, tackle, and swinging jib

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A paper prepared for for the Philadelphia Convention. The author, William G. Conner is foreman of the hardening room, George D. Whitcomb Mfg. Co., Rochelle, Ill.

crane the gears are placed over the quenching tank and lowered to the required depth vertically into a good grade of quenching oil. When they are removed still warm they are plunged into a clear cold water bath which tends to crack off or loosen the black film that collects from the oil bath. This leaves the parts fairly clean.

For hardening cast steel the heat usually is brought up gradually to 1440 or 1450 degrees Fahr. for the oil bath, and in dipping by the method just outlined there has been no complaint from the gears warping. They come out true and straight, with a good wearing surface on the teeth and hardened, with a case penetration of about 1/16 inch or better.

OBITUARY

JOSEPH WILLIAM RICHARDS

JOSEPH WILLIAM RICHARDS, professor of metallurgy at Lehigh University, South Bethlehem, Pa., for 30 years and a well-known member of the American Society for Steel Treating, died suddenly of heart disease at his home in Bethlehem, Pa., Oct. 12. He was 57 years old, having been born July 28, 1864, in Oldbury, England. He was internationally known as a metallurgical and chemical engineer and for his expert advice in litigation involving questions of metallurgy. At the time of his death, Doctor Richards was secretary of the American Electrochemical Society, a position which he held for many years. Professor Richards was the first president of the American Electrochemical Society and at one time was vice president of the American Chemical Society and a member of its council.

His early education was completed in Philadelphia high school from where he went to Lehigh, taking the chemical course and graduating in 1886. Later he studied in Heidelberg and Freiberg universities, Germany. In 1897 he was appointed a member of the United States Assay Commission and in the same year was made president of the chemical section of Franklin Institute, Philadelphia. He represented the institute at the International Geological Congress in Russia that year and two years later was made a member of the jury of awards in the chemical division of the National Export exhibition at Philadelphia. He served in a similar capacity at the Panama-Pacific exposition in 1915. For three years to 1918, Doctor Richards was a member of the United States Naval Conservatory Board.

Doctor Richards was the author of Aluminum; Metallurgical Calculations, Part I; General Metallurgy, Part II; and Iron and Steel; articles on metallurgy in Chandler's encyclopedia and many contributions to scientific journals. He translated Electrolysis of Water; Electrometallurgy in Chromium; Arrangement of Electrolytic Laboratories; and Electrolytic Production of Metallic Objects. In addition to the American Society for Steel Treating and the American Electrochemical and the American Chemical societies, Doctor Richards was a member of the Faraday Society, the Deutsche Bunsen Gesellschaft, the American Institute of Mining and Metallurgical Engineers, the American Iron and Steel institute and other technical societies.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

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MOORE, F. GUY, (M-9), 54 Chestnut St., Jamestown, N. Y.
NIMICK, T. HOWE, (M-10), Colonial Steel Co., Keystone Bldg., Pittsburgh, Pa.
PASMORE, E. H., (A-9), Columbia Tool Steel Co., 552 W. Lake St., Chicago, Ill.
PENFIELD, EARLE A., (M-9), Frasse Steel Works, Inc., Hartford, Conn.
POLE, EDWARD, (M-10), 8 Sharon St., Geneva, N. Y.
RIES, E. F., (M-10), Harrison Pike, Sta. L, P. O. Box No. 25, Cincinnati, Ohio.
ROSS, ERLE F., (M-10), The Iron Trade Review, Cleveland, Ohio.
SCHMITT, FRANK, (M-9), 811 W. Lafayette Blvd., Detroit, Mich.
SCHUMACKER, IRWIN C., (A-9), Midvale Steel & Ordnance Co., McCormick Bldg., Chicago, Ill.
STEWART, P. E., (M-9), Transue & Williams Steel Forging Co., Alliance, Ohio.
STUBING, A. F., (M-10), care Railway Mechanical Engr., 232 Broadway, New York City.
THOMSON, W G. H., (M-10), 1455 West 37th St., Chicago, Ill.
THORPE, S. T., (M-10), Horton Mfg. Co., Bristol, Conn.
TRAVIS, CHARLES, (M-9), 718 18th St., Rock Island, Ill.
TREADWAY, T. G., (M-10), Horton Mfg. Co., Bristol, Conn.
WOOD, EDSON, (M-9), 315 Bay St., Springfield, Mass.

CHANGES OF ADDRESS

ALBERS, L., JR. from 95 Brandt Place, New York City, to 175 Bleecher St., Brooklyn, N. Y.
AVERY, JAMES H.—from 257 W. Exchange St., Providence, R. I., to National Ring Traveler Co., P. O. Box 1256, Providence, R. I.
BOHNER, CARL M.—from 652 Market St., to 357 E. Buchtel Ave., Akron, Ohio.
BRANIGAN, PAUL J.—from 131 College Place, to 447 S. Beech St., Syracuse, N. Y.
COOPER, CHAS. H.—from North East Elec. Co., Rochester, N. Y., to Philmont, New York.
DICKSON, LIEUT. T. C.—from U. S. Ordnance Dept., Watertown Arsenal, Watertown, Mass., to the University Club, Golden Hill Rd., Bridgeport, Conn.
DIEDERICHS, WM. J.—from Timken Roller Bearing Co., Columbus, Ohio, to 1027 Lincoln Way, Ames, Iowa.
FARNSWORTH, GROVER,—from Oakland Motor Car Co., Pontiac, Mich., to 2981 East Grand Blvd., Detroit, Mich.
GEPHART, H. O.—from 600 George St. to 57 Whalley Ave., New Haven, Conn.

GILMOUR, M. L.—from 406 Hennepin Ave., Dixon, Ill., to 316 McKinney Ave., Houston, Texas.
GOSZTONYI, V. A.—from 1714 Quarrier St. to 3 Curry St., Armor Park, South Charleston, W. Va.
HARDER, PROF. OSCAR E.—from University of Minnesota to 707 University Ave. S. E., Minneapolis, Minn.
HAYDOCK, JOHN JR.—from Niles-Bement-Pond Co., Plainfield, N. J., to 111 Broadway, New York City.
HAYWARD, HENRY E.—from Link Belt Co., Dodge Plant, to 1835 N. Delaware Ave., Indianapolis, Ind.
HOLSBERG, W. A.—from 112 Clybourn St., Milwaukee, Wis., to 107 Sheffield Ave., Buffalo, N. Y.
HULBERT, L. G.—from Hares Motors, Inc., Bridgeport, Conn., to 4524 Avery Ave., Detroit, Mich.
JOSEPH, CARL F.—from 4845 Concord to 7420 Third Ave., Detroit, Mich.
KENNEDY, M. W.—from 2031 E. Dauphin St. to 5013 Smedley Ave., Philadelphia, Pa.
KRUGER, LOUIS R.—from 4622 N. Racine Ave. to 4522 N. Magnolia Ave., Chicago, Ill.
LARDNER, JAMES F.—from 723 20th St., Rock Island, Ill., to Y. M. C. A. Moline, Ill.
LARNED, LIEUT ELMER—from 6341 Kimbark Ave. to Interstate Iron & Steel Co., East Chicago, Ind.
MAROT, EDW. H.—from Steel Treating Equip. Co., 7939 Lafayette Blvd., to 2301 West Euclid Ave., Detroit, Mich.
McANIFFE, HUGH F.—from Moores-Philadelphia to Holmes, Del. County, Pa.
REICHHELM, P. R.—from American Gas Furn. Co., to American Swiss File & Tool Co., 24-26 John St., N. Y. C.
RICHARDS, W L.—from 1128 Stratford Ave., Stratford, Conn., to 89 Chatham St., New Haven, Conn.
ROBERTS, LAWRENCE J.—from 1287 Military Ave. to 1309 Military Ave., Detroit, Mich.
ROSEN, JOE—from Troy Foundry Mach. Co., Chicago, Ill., to Harms Hotel, Rock Island, Ill.
VAN AUSDALE, JOHN S.—from 1908 Harrison St. to 1912 Harrison St., Davenport, Iowa.
WHITE, FRANCIS GUY—from 10 Portland Place to North Side Y. M. C. A., Grand and Sullivan Aves., St. Louis, Mo.
WOLNICK, H. F.—from 2502 Eastwood Ave. to 2231 San Jose Ave., Chicago, Ill.

MAIL RETURNED

EVANS, H. J., Ridge and 14th Ave., New Kensington, Pa.
HORN, S. C., (M-10), Wilson Maeulin Co., P. O. Box 1351, Pittsburgh, Pa.
HURLEY, WM. B., 2985 West Blvd., Detroit, Mich.
SMITH, HENRY BOYNTON, New Britain Machine Co., New Britain, Conn.

News of the Chapters

METALLURGY COURSE MAKES FLYING START

By Paul C. Tris

JOHN F. KELLER

EVENING courses in metallurgy inaugurated in 1920, at Lewis Institute, Chicago, by the Chicago Chapter of the American Society for Steel Treating, swing into their second year with greatly increased momentum. Most of the credit for the success of these courses must be given Prof. John F. Keller, formerly of Purdue University, Lafayette, Ind., who was national president of the Steel Treating Research Society, which combined with the American Steel Treaters Society in 1920 to form the present great national organization.

In fifteen years of instructional work in forging at Purdue University, Professor Keller has gathered a prodigious number of lantern slides illustrating every step in the manufacture, treating, and handling of steel and iron in all its forms and variations. Lectures which occupy only a small part of the course in comparison with the time spent in actual work done by the students, are thus enlivened with an interest far beyond the usual. This year films are being used.

The following announcement was sent out recently to all firms having representatives in the membership of the American Society for Steel Treating:

ANNOUNCEMENT

"HEAT TREATING OF IRON AND STEEL"
"METALLOGRAPHY OF IRON AND STEEL"

Lewis Institute offers the above courses to a limited number of students, in evening classes of 15 weeks, two evenings a week.

The courses are open to students and industrial employes who have had practical experience or preparation; such as, Blacksmiths, Tool Hardeners, Tool Makers, Foremen, Superintendents, Heat Treaters, Metallurgists, Chemists, Inspectors, Salesmen.

Classes are limited to size and all enrolling after the quota is filled will be placed in classes to follow.

Classes in "Heat Treatment of Iron and Steel" meet Monday and Wednesday, 6:20 to 9:40 p. m., beginning Oct. 10, 1921.

Classes in "Metallography of Iron and Steel" meet Tuesday and Thursday, 6:20 to 9:40 p. m., beginning Oct. 11, 1921.

Tuition fee $20.00 for each course, payable in advance.

For further information call or write, Lewis Institute, 1930 West Madison Street, Chicago, Ill.

A synopsis of the course was also enclosed as follows:

COURSE 3-B—HEAT TREATMENT

1—Manufacturing methods—ore to finished product.
2—Methods of determining grades. The spark method.
3—Crystalline structures—Effect of heat and mechanical working on the structures of iron and steel.
4—Pyrometry—Various methods of measuring temperature.
5—Critical temperatures—Methods of Determination.
6—Forging—Theory and fundamental—The effect of improper methods.

FIG. 1—SOME OF THE EQUIPMENT IN THE HEAT TREATING DEPARTMENT OF LEWIS INSTITUTE, CHICAGO

7—Annealing and normalizing.
8—Hardening and Strengthening—Proper methods for obtaining certain physical properties.
9—Quenching—Methods and mediums.
10—Warping and cracking—Reasons and preventative methods.
11—Testing—For hardness and physical properties.
12—Tempering—Methods and procedure.
13—Special steels—Heat treatment.
14—Illustrated lectures and demonstrations on the "Uses of Metallography."
15—Methods of case hardening and the various heat treatments—Selective hardness.
16—Exercises in the above phases of the work will be included in the course given students in the forge and heat treatment department.

The equipment of the heat treating department as shown in the accompanying illustration, Fig. 1, is all new and as complete as it is possible to procure. Shown from left to right in this illustration are the lead

pot, oil drawing furnace cyanide pot, muffle furnace, high speed furnace, large tool or small die furnace, a three temperature high speed furnace, large carburizing or hardening furnace and an electrical resistance type furnace. These furnaces are all equipped with pyrometers connected in series with recording instruments, while the electric furnace, shown more in detail in Fig. 2, has a recording instrument for obtaining graphic heating curves and critical temperature charts. The entire heat treating department is located in the forge shop, where unequalled facilities are provided for forming and fabricating the tools for hardening and tempering by the students. Classes as large as can be handled have here full equipment for actually undertaking any process of tool making or of heat treatment.

The course in metallography aims to remove the usual objections of plant managers and superintendents that their metallographists are unable to diagnosis their photomicrographs. The course in heat treating and metallography being conducted simultaneously renders the course of special benefit as to actual work. The course is as follows:

COURSE 3-D—METALLOGRAPHY

To meet the demand for scientific information concerning the microstructure of metals, Lewis Institute is offering an evening course in the principles of metallography as applied to the investigation of iron and steel.

This course will embrace a study of carbon steel, tool steel, high speed, alloy steels, cast iron, and wrought iron. Photomicrographs will be made of many of the specimens. Students will perform all work in connection with the preparations of the samples, exactly as done in commercial laboratory practice.

This work will be of great value to chemists, inspectors, heat treaters, steel salesmen; or in fact to anyone connected with the metal industry.

1—Pure Metals—Their structure.
2—Longitudinal and transverse sections.
3—Grain size.
4—Quenching effects on manganese steels.
5—Quenching effects on high carbon steels.
6—Drawing effects on high carbon steels.
7—Effects of heat treating tool steels.
8—Etching solutions on high carbon.
9—Case hardening.
10—Effects of overheating.
11—Drawing high speed steel.
12—Effects of cold working on steel.
13—Examination for phosphorus and sulphur.

A horizontal metallographic outfit of the newest type made by the Bausch & Lomb Optical Co., Rochester, N. Y., and taking up to 8 x 10-inch negatives at magnifications of from 25 to 1000 diameters is used. The motor driven polishing table will accommodate eight students, the polishing heads having interchangeable disks. The school is also provided with tensile, torsional and hardness testing machines of the latest type and highest capacity.

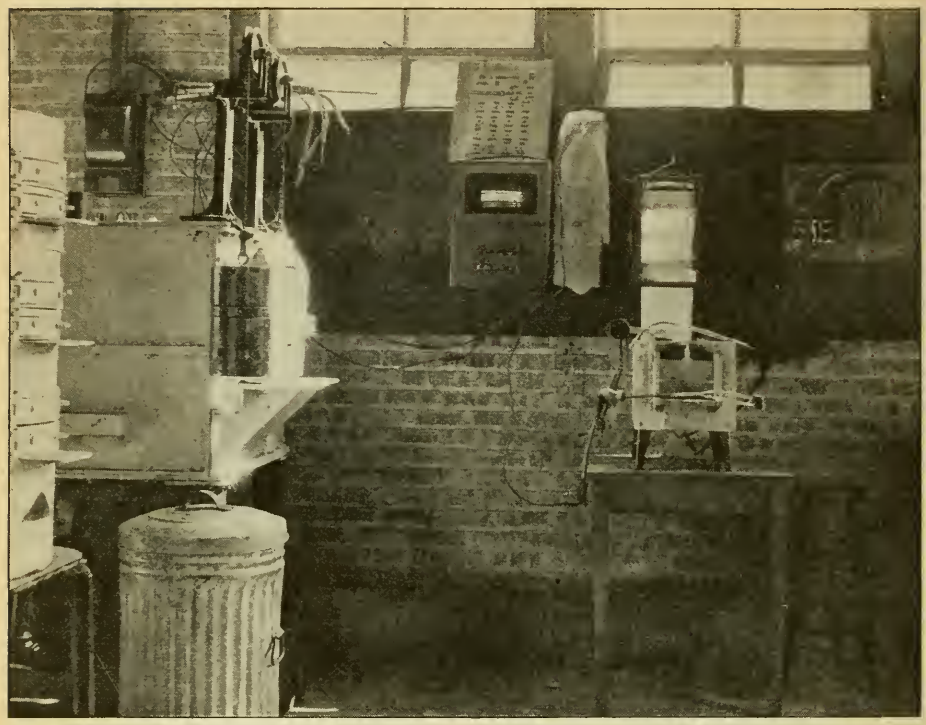


FIG. 2—THE ELECTRIC FURNACE AND RECORDING INSTRUMENT FOR OBTAINING GRAPHIC HEATING CURVES AND CRITICAL TEMPERATURE CHARTS

Judging from last year's experience and this year's flying start there is little doubt but that Lewis Institute will enable many men to become expert metallurgical workers.

PROVIDENCE CHAPTER

The Rhode Island chapter held its first meeting of the 1921-1922 season on Wednesday, Oct. 5, in the rooms of the Providence Engineering Society. K. A. Juthe, American Metallurgical Corp., Boston, presented a very fine paper. At the close of the paper an interesting discussion followed. It was announced that all future meetings will be held on the first Wednesday of each month, and talks will be presented upon the manufacture and treatment of steel.

WORCESTER CHAPTER

The Worcester Chapter of the American Society for Steel Treating met on Oct. 13 at the National Metal Trades Association rooms, Worcester, Mass. Wheaton B. Byers, President of the New England Metallurgical Corp., formerly assistant metallurgist at the Watertown Arsenal, delivered a paper on "Carburizing". The paper covered the history, theory, and modern practice in carburizing.

A very lively discussion followed the paper, in which all the members participated. Visitors were present from Boston, Springfield, and Provi-

dence chapters, and expressed the feeling that the Worcester organization was a very live number.

The Executive Committee of the Chapter met on Oct. 5, and it was decided that the Chapter shortly would institute a class in elementary metallurgy and metallography as applied to iron and steel. V. E. Hillman, Chairman of the Worcester Chapter, has volunteered his services, inasmuch as he has had experience prior to this and conducted classes of this nature. His lectures are all prepared and the fee of $5.00 will be charged for members. No one will be admitted to the course except members.

A big increase in membership is expected before our next meeting.

Chairman Hillman at the opening of the meeting spoke as follows:

"Before the principal speaker of the evening is introduced, I wish to make a few brief remarks regarding the policy of the Worcester Chapter for the ensuing year.

"Your Executive Committee will make every effort to present subjects which are of a practical nature, subjects which you will be able to digest, subjects which are not shackled with deep theory. There appears to be some divergence of opinion, however, as to the best plan of procedure to follow when the various chapters of the National Organization are in session.

"Personally, I firmly believe that each Chairman is confronted with a proposition that is a case unto itself. Conditions and influences vary in different sections of the country. Ways and means which are applicable to one chapter may be wholly unfit for another. Therefore, it is incumbent upon each chairman to cater to the whims and fancies of his constituents. If the members are not interested in the relationship which exists between cause and effect—discard the theory and impress upon the gentleman who is reading the paper the necessity of refraining from the use of such words as exfoliation, pseudo-martensite, and intergranular eutectic.

"Very few speakers are capable of imparting theoretical knowledge in a clear and concise manner. Many technical men are wont to use Latin and Greek terms. They shun the simple Anglo-Saxon word which carries weight, power, and conviction. What is the result? The audience easily loses the train of thought, the continuity of the discourse is broken, and the evening is stigmatized as being too theoretical, and beyond the grasp of the layman, who is equipped only with a grammar school education.

"Some of you gentlemen may feel that you are technical men, college bred, and capable of understanding Bielby's amorphous theory, the Widmanstaten structure, the mechanism of hardening, transformation points, etc.,—granted. But if we depend upon the technical men to keep the National Organization intact, our growth will be stunted. We will suffer decay, and eventually perish. We must cater to the masses, to the hardening room foreman, who has a vague conception of a solid solution; to the executive, who does not want to have his mind irritated by a pedantic metallurgist.

"Therefore, I shall summarize my remarks by stating first that this Chapter will function in accordance with the demands made upon it; secondly, the audience will be anticipated; thirdly, we propose to direct our appeal to the masses—the 'Men at the Fire.'"

The executive meeting of the Worcester Chapter on Oct. 5 decided

on the following form or procedure for the ensuing year, and it is explained by the copy of the following letter sent to superintendents of firms in Worcester and vicinity:

"The Executive Committee, Worcester Chapter of the American Society for Steel Treating convened Oct. 5 for the purpose of discussing a plan of procedure for the ensuing year.

"In addition to the regular monthly meetings, the Chapter decided to conduct a series of 15 lectures pertaining to the Metallurgy of Iron and Steel. An outline of the course is subjoined below.

Iron ores
Blast furnace
Acid open-hearth furnace
Basic open-hearth furnace
Bessemer steel
Electric steel
Fluxes
Ferroalloys
Various grades of steel
The elements: Sulphur, phosphorus, manganese, carbon, chromium, nickel, tungsten, vanadium.
Hardening, drawing, annealing, carburizing
Recalescence and decalescence points
Microphotographs and their practical application
Complete discussion of:
- Pearlite
- Martensite
- Troostite
- Sorbite
- Ferrite

Wrought iron:
- Slag fibers
- Transverse section
- Longitudinal section
- Segregation

Cast and malleable iron:
- Cementite
- Graphitic carbon
- The Brinell machine
- The scleroscope
- The tensile strength testing machine
- The metallographic bench
- The heat treating furnaces
- The different quenching mediums
- The various drawing baths

"Only members of the Society are eligible to enroll in the class. A fee of five (5) dollars will be charged to cover the expenses incident to conducting the course.

"The Executive Committee is writing to inquire if you will notify the men in your plant who may be interested—foremen—subforemen, men in the heat treating department, salesmen, executives, tool makers, in fact, any one who is seeking a general knowledge of steel metallurgy.

The class will meet on either Tuesday or Thursday evening—time 7:00 to 8:15 p. m.—central location.

Address all communications to the Chairman of the Executive Committee, Commonwealth Club, State Mutual Building, Worcester, Mass."

TRI CITY CHAPTER

The Tri City Chapter held its meeting at the Davenport Chamber of Commerce on Thursday evening, Oct. 13. N. B. Hoffman, metallurgist of the Colonial Steel Co., presented a paper on the "Effect of Hot Rolling and Cold Drawing on Steel Wire". Dr. Hoffman is an authority on this

subject, as he has had wide experience in connection with the manufacture of steel, and his paper was very interesting to the large number in attendance.

CLEVELAND CHAPTER

The September meeting of the Cleveland chapter was held at the Cleveland Engineering Society's rooms on the mezzanine floor at Hotel Winton, on Friday evening, Oct. 30. An interesting paper was presented and discussed. Immediately following interesting reports of the Indianapolis Convention were received.

ROCHESTER CHAPTER

A well attended meeting was held on Tuesday, Oct. 4, at the Camera Works department, Dr. N. B. Hoffman, metallurgist of the Colonial Steel Co., presenting a very interesting paper covering matters of importance to everyone connected with the use, purchase or sale of steel. Dr. Hoffman's interesting paper was illustrated by lantern slides and most thoroughly appreciated.

CINCINNATI CHAPTER

The September meeting of the Cincinnati Chapter was held at the Ohio Mechanic Institute on Friday, Sept. 16. The speaker of the evening was Samuel Spaulding, of the Halcomb Steel Co., who presented an illustrated paper on alloy steel. The attendance was very satisfactory.

The regular October meeting was held at the Ohio Mechanic Institute at 8 P. M. on Friday, Oct. 21. A large number of members and friends were in attendance to hear a round table discussion of the Indianapolis Convention.

LEHIGH VALLEY CHAPTER

Lehigh Valley had its regular October meeting on Oct. 10 at the Board of Trade rooms at Easton, Pa. About 75 members and guests were in attendance. There were papers presented by S. S. Ball on "Ingots" and J. M. Sylvester on "Forging". The first meeting of the year proved to be a very interesting one and the discussion lively.

DETROIT CHAPTER

The first meeting of the year was held on Sept. 8 at the Board of Commerce building at 8 o'clock. Chairman Danse told of the plans concerning the affiliation of scientific societies in Detroit as well as plans for the Indianapolis Convention.

The October meeting was held on Oct. 13. H. J. Lawson spoke on "The Origin and Aims of Our Society". Mr. Lawson was one of the charter members of the Society and spoke pleasingly and entertainingly with reference to it.

The second part of the meeting was devoted to the discussion of high nickel steels.

ST. LOUIS CHAPTER

The first meeting of the year was held at the American Annex Hotel on Monday evening, Sept. 12. A round table discussion took place after the dinner which was followed by an important business meeting.

The October meeting was held on Oct. 21 at the Engineers' Club, 3817 Olive street. The speaker of the evening was Maj. James W. Mills,

superintendent of the open-hearth department of the Enameling and Stamping Co. Major Mills has had many years of practical experience in the manufacture of carbon steel and was extremely well qualified to discuss this subject.

The members of the chapter were particularly interested in making St. Louis the Pittsburgh of the West, maintaining that they make excellent steel from Illinois coal and Missouri ore. After the paper of the evening, a very lively discussion took place on open-hearth practice.

A special announcement for the season of 1921-1922 for the St. Louis chapter was that they had decided to discontinue the dinners and to have a permanent meeting place and a fixed night. Arrangements have been made with the Engineers' Club to hold all of the meetings in its hall. Beginning with November, all of their meetings will be held on the first Friday before the first Monday of each month at 8 P. M. The November meeting will be held on Nov. 11, and the December meeting on Dec. 9.

CHICAGO CHAPTER

The October meeting of the Chicago Chapter was held at the City Club on Thursday, Oct. 13. Lt. Col. A. E. White, director of the department of engineering research of the University of Michigan and first National President of the American Society for Steel Treating was to have been present to present a paper on "Alloy Steels", but due to unavoidable conditions, Col. White could not be present and his paper was presented by Professor Upthegrove, of the University of Michigan. The paper was particularly well received and a very interesting discussion followed. About 125 were presented at the dinner.

The following important notice was sent to all members of the Chicago chapter:

"We are confident that every member of the Chicago Chapter of the American Society for Steel Treating wants to make this a big year for our chapter. We have the largest membership in the Society and we want tne hearty co-operation of everyone to prove to the other chapters that Chicago is at the top in accomplishments as well as number of members. Start the year right by filling in the blanks on the attached card and attending our first meeting.

"Your executive committee wants your co-operation in making the coming meeting interesting and instructive to the very largest number of members possible. You can assist greatly by filling in the blank spaces with subjects or problems in which you are interested and would like to have discussed at one of our meetings.

"Your executive committee is very anxious to make all of our meetings of special interest to the practical and nontechnical members of our chapter and if possible to help them with their every day problems. We have made arrangements with the Chicago City club to hold all of our meetings there where we can secure the very best of accommodations for our members. Our meetings will be held on the second Thursday of each month. Be sure to reserve this date on your calendar for the upbuilding of the profession to which you belong. Outside speakers will present papers on alternate months and the other months will be taken up with practical discussions on our local problems. At these practical meetings we will have present men having exceptional experience in practical heat treating and metallurgy, so that all of our members can gain by their experience. We want you to bring your plant executives to all of our meetings. We want to show them that the results of our meetings mean dollars and cents in their pockets. Remember the meeting dates and all take an active part in the program for the coming year."

SCHENECTADY CHAPTER

A picnic was held on Sept. 15 at the Locomotive Club at 6 p. m. The members of the American Locomotive Co. challenged the General Electric Co. members to a baseball game and the challenge was accepted.

The name of the engineering professor who served as umpire was kept secret but even with all of these precautions it was impossible to determine which side won inasmuch as the score keeper went home after the first inning and took the score book with him.

Kid Nelson and Dick Murphy changed their quarters from Jersey City in order to put on an exhibition for the members.

A wrestling match between Pink Primmer and Slipper Alum resulted in a draw after a very high temperature had been reached. Both were immediately quenched in cold water.

The Executive Committee of the Schenectady chapter received a write-up in the Schenectady Gazette as follows:

"The executive committee of the Schenectady chapter, American Society for Steel Treating, selected the third Tuesday of each month for meetings. Meetings are to be held in Albany and Troy also. The Schenectady meetings will be held in the civil engineering building at Union college.

"An entertainment and papers committee was appointed to arrange programs for all regular meetings of the chapter. G. R. Brophy, metallurgist of the General Electric Co., was appointed chairman. Other members are J. L. McFarland, engineer, General Electric Co.; William L. Weaver, Ludlum Steel Co., Watervliet; P. A. Cuenot, engineer, and B. H. Magill, inspector, American Locomotive Co.

"A membership committee was also appointed, with L. F. Mulholland, assistant engineer of tests, American Locomotive Co., as chairman, aided by Enrique Touceda, consulting engineer, Albany; Benjamin Harmon, metallurgist, Watervliet arsenal; John B. Rice, electric furnace specialist and Richard Topham, tool treating department, General Electric Co.

"Schenectady chapter received honorable mention at the national convention of the society at Indianapolis this year. All meetings are open to the public. Talented speakers are engaged to deliver the lectures. The first regular meeting will be held October 18.

The regular October meeting which was held on Oct. 18 at the Union College Civil Engineering Building, had over 100 in attendance. A paper was presented by Dr. Willis R. Whitney, director of research of the General Electric Co., entitled, "Where Do We Go From Here?" Dr. Whitney handled his interesting subject in a very capable manner and it was thoroughly enjoyed by all present. H. H. Barker, Chief Chemist of the General Electric Co., gave a paper on "Radium Activity". Quite a number of entertaining numbers were held, consisting of singing, violin and piano selections.

MILWAUKEE CHAPTER

The September meeting was held at the Medford Hotel on Sept. 13, and the speaker of the evening was H. B. Knowlton, of the Milwaukee Continuation School, who presented a very capable paper on "Carburizing Materials."

The October meeting was held at the Medford on Tuesday Oct. 18, at 8 o'clock, preceded by a dinner at 6:30. The meeting was very largely attended, and interesting papers were presented by H. J. French, Bureau of Standards, on the subjects of "Some Effects of High Temperature on Steels" and the "Effects of Heat Treatment on the Mechanical Properties of Steel". The second part of the meeting was given to interesting reports of the Indianapolis Convention as well as to the discussion of molybdenum steel.

WASHINGTON CHAPTER

The October meeting was held in the auditorium of the New Interior Department building on Friday, Oct. 14. The subject in discussion was "High Speed Tool Steel".

In the absence of Secretary French, J. S. Vanick gave a brief outline of important events at the Indianapolis Convention. This was followed by the presentation of the paper on the "Constitution of High Speed Steel", by J. P. Gill, metallurgist for the Vanadium Alloys Steel Co.

The vigorous discussion which followed the presentation of the paper, revealed the interest of local members in the important problems relating to tool steel.

HARTFORD CHAPTER

The first meeting of the current season was held Thursday, Sept. 29, at the Hartford Electric Light Company's hall. Thirty-five members and guests attended. The meeting was addressed by Messrs. Gilligan, Gere, d'Arcambal, Moore and Stacks, who described different features they had observed at the National Convention. Mr. d'Arcambal also announced the program arranged for the remainder of the season.

Plans for increasing the membership of the chapter were discussed in connection with the New England area plan. Mr. Gere, Chairman, announced a plan to promote interest and discussion. At each meeting some member previously designated will be prepared to describe in detail some phenomenon or irregularity observed by him in his heat treating practice. It is hoped that this will stimulate discussion.

The first example of this was an irregularity observed in the heat treatment of ball bearing cones. These cones after a double treatment, namely, 1600 degrees Fahr. oil quench followed by a 1500 degree Fahr. oil quench, were tempered and tested with the file. The entire cone appeared file hard. After grinding the raceways, the ground surfaces were soft to the file. In order to reclaim them, the parts were requenched in oil from 1500 degrees Fahr. and tempered as before. The ground surfaces were still soft, whereas the remainder of the cone was file hard. Numerous experimental heat treatments were applied and examinations made to determine the reason for this phenomenon, but the only positive information developed was that the ground surfaces could be made file hard only by repeating the entire heat treatment, namely 1600 degrees Fahr. oil quench followed by 1500 degree Fahr. oil quench. If the 1600 degree Fahr. oil quench was omitted, soft raceways resulted.

Discussion of this phenomenon was lively, lasting for nearly half an hour.

The October meeting of the Hartford chapter was held in the Y. M. C. A. Assembly Hall on Thursday, Oct. 13. Professor John H. Nelson, of the Wyman-Gordon Co., presented the paper of the evening. About 105 were present.

Prof. Nelson's talk was illustrated with about 30 slides, covering design of crank forgings, defects in steel, and charts showing the variations in physical properties between steels of similar analyses made by different processes, also the effect of the drawing temperature on steels made by the different processes, as acid open-hearth, basic open-hearth, and electric furnace steels.

Discussion following his talk centered around "snow-flakes" and other defects in steel, "temper brittleness", and the relative merits of electric steels as compared with open-hearth.

NORTHWEST CHAPTER

The first meeting of the Northwest Chapter was held Friday night,

Oct. 14, at the Manufacturers' Club. There was the usual dinner at 6:30 with the program beginning at 7:30. The Northwest Chapter was fortunate in being able to secure H. J. French, of the United States Bureau of Standards, for this meeting. Mr. French discussed the mechanical properties of steels at various temperatures up to about 1200 degrees Fahr., and the effect of different heat treatments, and mechanical treatments, on the tensile strength, proportional limit, Brinell and Shore hardness, reduction of area, elongation, and impact toughness. We can most heartily recommend this address to any of the Chapters who can arrange to secure Mr. French.

A report of the committee in charge of the enrollment for the educational series of lectures showed an enrollment of about 30 at this time, and the committee expects this number to be increased to at least 50 by the time of the first lecture, Monday, Oct. 24.

SPRINGFIELD CHAPTER

The October meeting of the Springfield Chapter was held in the Chamber of Commerce rooms on Friday evening, Oct. 14. About 40 members and their friends were present.

Following a report by the Chairman on his visit to the Convention, a paper was read by Dr. Paul C. Doerr, New England representative of the Quacker Oil Product Co., on "Quenching and Tempering Oils, and Carburizing Materials." The paper, while covering a very broad field, was decidedly interesting and instructive. A good discussion followed.

PHILADELPHIA CHAPTER

A get-together meeing was held at the Engineers Club on Friday evening, Sept. 30. Reports from the Indianapolis Convention were received and J. L. DeMar, cartoonist for the Philadelphia Record, showed how he prepares his inimitable work.

The members did not have to bring their own smokes that night or sandwiches in their pocket, because the chapter had provided smokes and refreshments on tap.

The Philadelphia Chapter with the assistance of its capable Executive Committee has made arrangements with Temple University for a course in metallography during the coming year. An announcement and outline of the course are as follows:

To YOU who are interested in Steel, Greetings:

You well remember it was proposed that a course in Metallography be given under the auspices of the Philadelphia Chapter, American Society for Steel Treating, at Temple University. Enclosed please find an outline of the course.

Register at Temple University, Broad and Berks streets, at once. Mention the course to your friends and young men of your acquaintance who may be interested.

The Chicago Chapter of the Society gave a similar course last year, and it was a great success. The Philadelphia Chapter proposes to conduct a course at Temple University, which will be even more successful.

The course. The Course will be divided into two parts:

(a) Lecture Course. Thirty lectures, covering the process of manufacture, metallography, heat treatment, pyrometry and thermal analysis, physical and mechanical testing.

The lecture work may be taken without the laboratory work and will be made as clear, practical and elementary as possible. The lectures will be illustrated with experiments, lantern slides and films.

(b) Laboratory Course. Instruction in the laboratory will be made as practical as possible. The laboratory sections will be limited to twenty (20). The laboratory

will consist of instruction in practical shop methods. The work is so arranged that those having preliminary training may advance more rapidly than those having no preliminary training.

Instructors. Practical men, Members of the Philadelphia Chapter American Sosiety for Steel Treating, and experts in their line.

Date of opening. Monday evening, October 3rd.

Time. Seven-thirty (7.30) p. m.

Place. Chemical Lecture Room, Temple University, Broad and Berks streets.

Fees. Lecture Course, $10.00. Laboratory Course, $25.00. Those who take the laboratory course are required to take the lecture course. Total cost of the course, $35.00.

Equipment. A complete equipment has been installed by Temple University for the course. Gas and electrical furnaces, grinding and polishing machines, microphotographic apparatus, pyrometers, etc.

Days on which work will be given. Lecture—Monday Evenings. Laboratory Work—Section 1, Tuesday and Thursday Evenings. Section 2, Wednesday and Friday Evenings. The opportunity is given to you. Enroll at once either for the lecture course or the complete course.

Sincerely yours,

TEMPLE UNIVERSITY AND THE EXECUTIVE COMMITTEE OF THE AMERICAN SOCIETY FOR STEEL TREATING

OUTLINE OF COURSE

I—GENERAL DISCUSSION OF IRON AND STEEL

1. Processes of manufacture. (a) Blast Furnace. (b) Wrought Iron. (c) Cast Iron. (d) Malleable Iron. (e) Bessemer (f) Crucible Steel. (g) Open-Hearth Steel. (h) Electric Steel.
2. Rolling, Blooming, Cogging, Forging and Pressing, Drawing.

II—METALLOGRAPHY

1. Constitution Diagrams. 2. Use of Microscope. 3. Preparation of Specimens. 4. Structure of Iron and Steel.
(a) Pure Iron. (b) Wrought Iron. (c) Low Carbon. (d) Medium Carbon. (e) High Carbon.
5: Effect of Impurities. 6. Structure of Cast Steel. 7. Effect of Mechanical Working on Cast Steel. 8. Structure of Cast Iron. 9. Case Hardening.

III—HEAT TREATMENT

1. General Purpose of Heat Treatment. 2. Discussions of Annealing, Hardening, Tempering and Case Hardening. 3. Heat Treatment of Carbon and Alloy Steels. 4. Miscellaneous Treatments.
(a) Good. (b) Bad.
5. Fuel, furnaces and equipment.

IV—PYROMETRY AND THERMAL ANALYSIS

1. Temperature Scale. 2. Thermometers. 3. Thermocouples. 4. Resistance Thermometers. 5. Optical and Radiation Pyrometers. 6. Application of Pyrometers. 7. Thermal Analysis.
(a) Time-temperature Curves. (b) Differential Curves. (c) Inverse Rate Curves.
8. Equipment Used in Thermal Analysis.

V—PHYSICAL AND MECHANICAL TESTING

1. Tensile Tests.
(a) Tensile Strength. (b) Yield Point. (c) Proportional Limit. (d) Elastic Limit. (e) Elongation. (f) Reduction in Area.
2. Hardness Tests.
(a) Brinell. (b) Shore, etc.
3. Impact Tests.
(a) Charpy, Izod, etc.
4. Alternating Stress.

NEW YORK CHAPTER

The first meeting of the New York Chapter of the American Society for Steel Treating, in the regular series of monthly sessions for the 1921-1922 season, was held Wednesday evening, Oct. 19, at the Bush Terminal Sales Building, 132 West Forty-second street, New York. The chief speaker was Dr. John A. Mathews, president Crucible Steel Co. of

(*Continued on Page* 33)

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, December, 1921 No. 3

SOCIETY MAKES FURTHER PROGRESS

ANOTHER step in the progress of the American Society for Steel Treating is noted in the announcement that two sectional meetings will be arranged in 1922 in addition to the National Convention and Exhibition. This was a decision reached by the Board of Directors at its last meeting. As announced in greater detail on another page of this issue, the first of these meetings will be known as the Winter Meeting and will be held in New York during January or February, while the second meeting will be known as the Spring Meeting and will be held in Pittsburgh in May. According to present plans the meetings will be short but will be made of considerable value.

These meetings are certain to inspire greater interest in the activities of the Society, coming as they do at convenient intervals between annual metings. As is always the case with national conventions, but a small percentage of the membership finds itself able to attend because of distances to be traveled and the expense attached. The holding of sectional meetings, therefore, will enable a greater portion of the membership to come in contact with activity of the national organization. Members will be able to attend with a minimum of travel and expense. Advantages will therefore accrue to the members and the society at the same time. In a final analysis the strength of a society depends upon the interest of its members and this in turn depends upon what the society has to offer.

Principally the sectional meetings will be of a technical nature, with presentation of papers dealing with heat treating problems of particular interest to the membership located in those sections. Careful thought will be given to the selection of papers and to the authors and the papers will be limited to afford ample discussion. To further promote discussion, it is the intention to preprint the papers in TRANSACTIONS as well to distribute preprint copies. This feature alone should guarantee worthwhile meetings. It is to be hoped that the meetings scheduled for the coming year will be so successful that regular sectional meetings will become institutions in the work of the Society.

TECHNICAL PAPERS TO BE ABSTRACTED

BEGINNING with this issue, TRANSACTIONS has added a new feature, that of the printing of abstracts of heat treating and related papers distributed by technical societies or appearing in the trade and technical press. For some time it has been felt that a section of this nature would be of distinct service to members of the Society. In the preparation of

ELWOOD HAYNES

these abstracts it is not the purpose to review the subjects in any detail but to give sufficient information that the busy reader may be advised of any articles in which he may be interested. Each abstract will give the title of the article, the name of the author, and where the article may be found. As a further time-saver, the abstracts will be properly grouped according to their general nature.

ELWOOD HAYNES ELECTED TO HONORARY MEMBERSHIP

ELWOOD HAYNES, president of the Haynes Automobile Co., and Haynes Stellite Co., Kokomo, Ind., and widely known in automotive and metallurgical fields, was elected to honorary membership in the American Society for Steel Treating at the recent Indianapolis Convention. Probably Mr. Haynes is best known for his building of the first automobile although he has won considerable prominence through his inventions of stellite and stainless steel as well as the introduction of aluminum and nickel steel into automobile design. He was born at Portland, Ind., Oct. 14, 1857. In 1872 he invented an apparatus for making oxygen and succeeded in melting brass, cast iron and high carbon steel, using a furnace and blower of his own construction. He entered Worcester Polytechnic Institute, Worcester, Mass., in 1878 and graduated in 1881, having in the progress of his thesis discovered tungsten chrome steel.

During 1883-84 he was principal of the Portland high school, giving up that work to enter John Hopkins University, Baltimore, Md., where he took a post graduate course in chemistry and biology. From 1886 to 1890 Mr. Haynes was manager of the Portland Natural Gas & Oil Co., Portland, Ind. His first idea of the "horseless carriage" was conceived in 1887. In 1889 he became field superintendent of the Indiana Natural Gas & Oil Co., Chicago, with headquarters at Greentown, Ind. Drawings for the construction of his horseless carriage were made in 1891 and plans for its construction were completed in 1892 at which time he moved to Kokomo, Ind. The first trip in the carriage was made July 4, 1894. The same year Mr. Haynes invented a successful carburetor and the first automobile muffler. Use of aluminum into automobile construction was introduced in 1895 and nickel steel the following year.

An alloy of chromium and nickel containing carbon and silicon was discovered in 1897 and the next year an alloy of pure chromium and pure nickel was formed. In 1899 he made the first 1000-mile automobile trip in America, going from Kokomo to New York City. A rotary valve gas engine was invented and built in 1903. Mr. Haynes in 1906 made his basic invention of stellite for use in table and pocket knives, etc., this alloy being composed of nickel or cobalt with chromium. The basic patent on stellite was obtained in 1907. In 1912 he improved the invention of this alloy to include use in high speed metal cutting tools. Stainless steel, or rustless steel, was invented the same year.

In addition to the American Society for Steel Treating, Mr. Haynes is a member of the Iron and Steel Institute of Great Britain, American Chemical Society, International Congress of Applied Science, Society of Automotive Engineers and the American Institute of Metals.

TWO SECTIONAL MEETINGS ARE ARRANGED

AT THE regular meeting of the Board of Directors of the Society held on Oct. 29, at Cleveland, it was decided that two sectional meetings would be held in 1922 in addition to the regular Convention and Exhibition. The first of these two meetings will be known as the Winter Meeting and will be held in New York during January or February, the exact date to be determined shortly. The second meeting, to be known as the Spring Meeting, is to be held in Pittsburgh in May, the exact date of this meeting also to be announced later. It was the opinion of the Board of Directors and National Officers that these meetings arranged between National Conventions will promote greater activity of the Society, since many members unable to attend the national meetings will be able to attend the sectional meetings. Sessions will be limited to not more than two days and will include consideration of technical papers. A few carefully selected and important papers will be read and ample time will be provided for their discussion. To promote discussion, these papers will be printed in issues of TRANSACTIONS preceding the meetings and in preprint form although due to lack of time this plan may not be completely carried out for the Winter Meeting. It is also announced that a Board of Directors meeting will be held in connection with each of the two meetings.

After considerable discussion concerning the place for the 1922 Convention and Exhibition, the Board selected Detroit. This city was selected for two reasons: First, because it is a central location as far as the membership is concerned; and second, because it is a large heat treating center as a result of the automobile industry. The date for the Convention has been set as Sept. 25 to 30. Another important action of the Board of Directors was that of indefinitely suspending the initiation fee for membership in the Society.

TRANSACTIONS INDEX IS READY

AN INDEX for Vol. I of TRANSACTIONS has been prepared and is now ready for distribution to readers. A copy may be obtained upon request to the National Secretary, 4600 Prospect avenue, Cleveland. It contains the names of 84 authors. For convenience in finding articles, the cross index method has been used, some 300 subjects being listed. To facilitate binding, the index is printed in pamphlet form and the same page size as TRANSACTIONS.

NEW CHAPTER IS ESTABLISHED AT ROCKFORD

THE new chapter of the American Society for Steel Treating established at Rockford, Ill. by the granting of a charter in October is now organized and will hold its opening meeting Monday evening, Dec. 12. The meeting will be held at the Nelson hotel and will be preceded by a dinner. The National Secretary, W. H. Eisenman, will be the guest of the Chapter. A technical paper will be presented at the meeting but the speaker and subject have not been announced.

Two preliminary meetings have already been held for the purpose of organization and election of officers. The officers selected were: Chairman, O. T. Muehlemeyer, metallurgist, Barker-Coleman Co., Rockford, Ill.; vice chairman, O. H. Harrison, Rockford, Ill.; and secretary-treasurer, R. M. Smith, 829 North Court street, Rockford, Ill. The new chapter has made a flying start and has already enrolled over 35 members. Manufacturing interests in Rockford have enlisted their support.

A NOTABLE MOVEMENT IN METALLURGICAL EDUCATION

A DEFINITE educational movement for the benefit of the "man at the fire" is one of the fundamental aims of the American Society for Steel Treating. Not only is this aim stated in the constitution of the society, but the national officers bear this responsibility in mind. This in turn is doubtless due to a constant urge from the membership, voiced through the officers of the 31 local sections, or chapters, so called. All the directors realize that the phenomenal growth of the society has risen from a desire on the part of the skilled heat treater to acquire some technical and theoretical information on his daily work. This desire must not be disappointed; otherwise the decline of the society will be as rapid as its rise.

"A most pretentious effort in educational lines is sponsored by the important chapter at Chicago. Over a year ago it induced the president of Lewis Institute to provide facilities for an evening course in metallurgy, and secured the services of Professor John F. Keller, of Purdue, to direct the work. Several specialists also volunteered to lecture on certain phases of heat treatment. This effort proved such a gratifying success that now two separate courses are offered, one on heat treatment and the other on metallography of iron and steel, each extending over four months, and meeting for three hours two evenings each week.

"Such a program is obviously not beyond the resources of many of our technical colleges, and it appears to be one worthy of imitation. However, other local sections, notably those at Hartford, New York and Bethlehem, did not wait to perfect a working arrangement with some progressive school, but have laid out a well-considered program to occupy the regular monthly meetings, a program which will cover certain branches of the art in a systematic manner, each meeting to be addressed, in not too technical language, by an undoubted authority in his subject. The Hartford chapter demonstrated last year that such a series of meetings was very popular with the members. Knowing that the new president of the society, F. P. Gilligan, is a Hartford man, it is unnecessary to remark that his influence will undoubtedly support those members who desire to perform some service for brothers less fortunate in their technical education.

"Nor should such meetings be devoid of interest to the skillful metallurgist. One has only to read Professor Tyndall's fascinating lectures to know that it is possible to instruct both the expert and the layman. Of course, there are few Tyndalls, but now and then the feat so easy for him, so difficult for others, is attained; witness Dr. John A. Mathews' masterful address recently given in New York on "What Is Steel?" Commonplace facts stated with precision and interpreted with that discrimination which comes unbidden from many years' experience gives not only instruction to the tyro but a new perspective to the specialist."

The above is an editorial which appeared in the Nov. 9 issue of *Chemical & Metallurgical Engineering*, page 858.

ADDRESSES PRESENTED AT THE THIRD ANNUAL CONVENTION BANQUET

ONE of the features of the Third Annual Convention banquet of the American Society for Steel Treating, held at the Claypool hotel, Indianapolis, Sept. 22, was the unusual program of addresses which had been arranged. The speakers were representatives of other large technical societies, however, their subjects of discussion were such as to be of mutual interest to all technical organizations. Dr. Albert Sauveur, professor of metallurgy, Harvard University and honorary member of the American Society for Steel Treating, presided as toastmaster. Professor Sauveur's remarks and the various addresses are printed in part in this article.

TOASTMASTER SAUVEUR: I think in justice to myself I ought to tell you that my task as toastmaster has been made rather difficult. Not being a professional toastmaster, being rather a man of slow wits, it makes the matter a little more difficult. I believe you will agree with me if I say that teachers of applied science have contributed their share to the development of this country. It is therefore appropriate that we should have on our program some professors. Being myself a professor, I feel some hesitancy about this matter. However, I am somewhat relieved at the thought that the gentleman I am going to call on next is more than a professor, he is dean. I am glad, because some people have not a great esteem for professors. And I would give you an instance of that.

There was a gentleman from the South once who found himself in the unfortunate position of having to introduce to the public a colored man, and he said "Of course I didn't want to call him 'Mr.' and I couldn't say 'The D—n Nigger,' so I called him 'Professor.'" Gentlemen, I am going to introduce to you a distinguished mechanical engineer. He is the representative at this meeting of the American Society of Mechanical Engineers, he is a distinguished teacher of mechanical engineering of the old and honored university from which many distinguished engineers have graduated, Dean A. A. Potter, of the engineering schools of Purdue University, Lafayette, Ind., who will speak to us on the subject of "The Engineering Society and Public Service."

Address of Dean A. A. Potter

DEAN POTTER: Mr. Toastmaster, Lt. Col. White, Governor McCray, Mayor Jewett, members and guests of the American Society for Steel Treating. I have the honor of greeting you as a representative of the American Society of Mechanical Engineers.

Now in order to give you some variety in the speaking program, I shall make use of a manuscript, and also for the purpose of giving the reporter an opportunity to discover what makes my inflections so different from those of the other speakers.

I have the honor of greeting you as a representative of the American Society of Mechanical Engineers. This society was founded about 40 years ago for the purpose of promoting the arts and sciences connected with engineering construction. It has at present about 15,000 members who welcome every opportunity to co-operate with other organizations in developing our industries and in adding to knowledge of value to human welfare.

The American Society of Mechanical Engineers is in its aims funda-

mentally educational. It has 39 local sections in different parts of the country and about 50 student branches in the leading engineering colleges and universities. To best serve the specialties of its members, the society has technical sections dealing with power, fuels, ordnance, shop practice, and other branches of mechanical engineering.

Its research committee is a clearing house for engineering investigations and keeps the public in touch with research results, research in progress and research equipment available. This committee has also subcommittees on bearing metals, action of cutting tools, fluid meters, heat transmission, lubrication, accuracy of engineering instruments and vibration stresses of shafting.

The standardization work of the society is concerned at present with the power test codes, the boiler code and the safety codes. The society also co-operates with the American Engineering Standards Committee by recommending standards within the mechanical engineering field.

The activities of the American Society of Mechanical Engineers are not confined to the purely technical questions which are strictly within the professional needs of its members. Much emphasis is placed on service to the community, to the state and to the nation. The society gives considerable attention to problems which affect industry and public welfare. It is being realized more and more that the mechanical engineer is concerned not only with the performance of machines but also with that of men. He is interested in promoting harmonious working of the agencies of capital and of labor. He appreciates that the welfare of the worker is the concern of the public, but knows that human rights and property rights are interdependent; that the security of one depends upon the other.

During these times of unrest, which are too prevalent to be overlooked, it is absolutely necessary that technical societies should take an active and leading part in properly guiding public opinion. We cannot expect the return of prosperity unless our people are interested in eliminating class consciousness and mob control. We must develop in the public mind a more tolerant attitude toward the development of our national resources, transportation and manufacturing under private control.

Technical societies such as the American Society for Steel Treating and the American Society of Mechanical Engineers should co-operate in solving problems of interest to industry and humanity. They should also take an active interest in the education of men for industry and should give encouragement to technical research.

Modern industrial conditions have resulted in a greater realization than ever before of the value of technical education and of industrial research. Engineering educational institutions on the other hand are recognizing their opportunity for service in connection with the problems of industry and feel that such a point of contact makes their instruction and their experimental work more practical and more useful.

Our technical universities to best serve industry should accomplish two things: First, they should produce through their resident instruction thinking men who can handle human as well as material problems. This can be accomplished only if the greatest emphasis is laid on the teaching of men and not of subjects, if the instruction is based upon each student's ability, knowledge and experience, and if every effort is made to develop in each student initiative, judgment, co-operative ability, sense of responsibility and the other personal qualities so essential in industry.

All engineering instruction should not be limited to the purely technical phases of design, construction and operation, but more attention should be given to develop men who can also handle the administrative and financial phases of industry.

The second function of a technical university is to carry on investigations and experiments of value to industry and to the public. Research goes hand in hand with good teaching, as a person receives his greatest development if he learns to take new paths instead of remaining in a rut. We are living in an age which places a premium on initiative, the power to take the lead, to plan, to originate. To develop leaders for industry we must not limit our training to the past, but we must instill in our students the desire to take new paths, to try new experiments, to look ahead and to develop the power of initiative. Industrial research carried on at our laboratories is of value in stimulating the students to become leaders in the search for nature's truths.

It is a well known fact that industrial research has been until recently greatly neglected in the United States. We were fortunate in having such genius among our people, but we have given too little attention to development of fundamental truths. The United States with 6 per cent of the world's population is responsible for over two-thirds of the epoch making invention of the past century. The telephone, the telegraph, the typewriter, the cash register, the adding machine, the incandescent lamp, the talking machine, the electric furnace and the movie are only a few of our great inventions. The great natural resources of this country have enabled us to supply two-thirds of the world's supply of oil, copper and aluminum, nearly half of the world's supply of coal, zinc, iron, steel and lead and more than one-fifth of the world's supply of gold. Our progress and accomplishments of the future will be even greater than they have been in the past if we pay greater attention to research.

It is hoped that in the near future when the business of the country improves, societies such as the American Society for Steel Treating will find it possible to encourage research at technical universities by establishing industrial fellowships and research professorships. Your society can at present best aid technical education by appointing visiting committees, similar to those established by the American Railway Engineering Association, and for the purpose of advising our engineering colleges concerning lines of study and research in connection with steel treating.

With reference to the last statement, the American Railway Engineering Association has visiting committees that make an inspection of the equipment and the work of half a thousand or so institutions distributed in different parts of the country, and I can say that those committees have been a great stimulus to the work of Purdue University. Again, I beg to extend you greeting on behalf of the American Society of Mechanical Engineers.

TOASTMASTER SAUVEUR: Dean Potter has told us things worth hearing and things with which we in the main, at least, are sympathetic. It is only this morning that I knew of the next speaker I am going to call upon. I didn't even have time to look into "Who's Who." Fortunately, I know him very well; he is one of my colleagues of Harvard University, and I hope I may say that he is one of my friends. I know

many things about him, all good things. I know that he is a very distinguished electrical engineer, that he is a distinguished teacher of that subject; I know that as chairman of the welding committee, as chairman of the Engineering Division of the National Research Council, as chairman of the engineering standards committee, and probably as chairman of other committees, he has rendered a service to the engineering profession and to the country of a very high order. I take great pleasure in calling on Professor C. A. Adams.

Address of Prof. C. A. Adams

PROFESSOR ADAMS: Mr. Toastmaster, ladies and gentlemen: I wish to apologize for taking a subject which is not on the program, a subject which I sent in when I was first notified of the desire to have me speak this evening. After I sent that subject in your President asked me if I would talk on the "National Aspects of Research" or at least make some reference thereto. But I had to write him and tell him that I had promised to make an address on that same subject at one of your meetings, so the real subject of my talk this evening is "The Spirit of Research in Engineering and Industry."

Some years ago I had a very excellent lesson. I had prepared a highly technical paper for the American Institute of Electrical Engineers. It came at the end of a long session and everybody wanted to get away. I got up and stated the substance of the paper in two sentences—short sentences—and said that anybody who wanted to get the information, the technical information, therein could read it, and sat down. I received great applause and two or three highly commendatory remarks from the presiding officer and others, and was led to feel that I had done a great job. Afterwards, in thinking it over, when my pride cooled down a little bit, I came to realize since that the reason for the rejoicing and the complimentary remarks was that I had released the company without a long harangue. Therefore, in order to be sure that I might not subject you to a long harangue, I have written out my comparatively brief remarks, which I will read to you.

Incidentally, I am going to criticise my own profession of teaching, and the engineering profession as well, and if the metallurgists and those of you here who are interested in research are not open to this criticism, I hope you will not take it unto yourselves, because I am not a metallurgist, and am not so familiar with the conditions in your profession as I am with those in the engineering profession.

Our conception as to what constitutes research, as well as to the value of research to the industries of the country depends so much upon our training and experience, that it may be well to start by presenting to you a picture of the relations between science and industry, which has been gradually developing more and more clearly in my mind during 30 years of endeavor in which the major interest has been the application of science to the solution of industrial problems.

On the one hand we have the reservoir of scientific knowledge, the result of centuries of patient research by the world's great scientists; and on the other hand industry, brought to its present state of evolution for the most part by practical men employing largely empirical methods The exceptions to this statement in some cases are striking but not numerous; and even in these exceptional cases the use of scientific knowledge and scientific method is of recent date. Moreover, in mo-

of these cases the extent of the application is as yet exceedingly limited.

Thus it is not stretching the facts to indicate in our picture a considerable gap between science on the one hand and industry as a whole on the other. In this gap stands the engineer, but unfortunately for industry he fails to bridge the gap, except in a few exceptional cases. As this is a vital part of my picture and also an important part of the foundation for the message which I hope to convey to you at this time, I am going to risk boring you and perhaps shocking you by giving you my reasons for this statement. My conviction on this point is the result of 30 years of teaching engineering combined with an unusually extensive contact with industry. If the statements I make seem somewhat emphatic, I ask your indulgence, but beg you to believe that I can support them with ample evidence.

Our engineering education is grossly superficial. Students are taught to do typical tasks or to solve typical problems by orthodox or established methods which are almost invariably approximate. They think that they are employing scientifically exact methods. They are taught the language of the profession by rote without any understanding of the reason why. They are crammed with information, but have no grounding in the elements of the sciences underlying their profession. Their memories are trained but not their power of analysis. They are not encouraged to make the subject their own or prepared to solve new problems. In short, they are not taught to think or to know when their starting point in analysis is sound or fundamental. In support of these statements I could recite illustrations by the hour, taken not so much from my teaching experience as from my contact with engineers in practice, many of them considered experts in their own fields.

Please do not think that I am setting before you an unreasonable or academic ideal; I know what can be done with average good raw human material; I know what is sadly needed in many of our industries and I know that many important problems could be solved easily by engineers with a sound fundamental training, even if they knew a little less about the so-called practical side of their profession. Neither have I in mind only the so-called research engineer. Every engineer should have the spirit of research, should be trained to scrutinize evidence of fact, to make sure of his foundation and to build up his analysis carefully and sure-footedly on that foundation. In other words, he should be something more than a machine, performing an operation just as it has been performed by many others before. Otherwise he is not an engineer worthy of the name.

In fact my creed is that this spirit of research should extend even farther down the line to the more humble employes, that they should be encouraged to understand a little of the reason why of their work, to think about it intelligently and to strive for improvements. This would not only make them more efficient but would also tend to make them more contented in their work and might aid materially in the solution of some of our troublesome labor problems.

To return to our picture of science and industry with the gap between, a few of our large corporations, realizing the value of bridging the gap, of tapping the reservoir of scientific knowledge and of applying this knowledge to the solution of their industrial problems, have established great research laboratories, officered not by engineers but for the most part by scientists. The annual operating costs of these laboratories

range from a few hundred thousands to $10,000,000, but the calculable savings, disregarding those benefits to the corporations as well as to the consuming public, which cannot be figured in dollars and cents, range from five to ten times the cost. No other expenditure yields anything like this return, and the accounts of some of the accomplishments of these research laboratories read like the story of "Alladin's Lamp."

But the research departments attack only those problems brought to them; there are numerous other possibilities for improvement never presented, because the engineers in charge of the work in question do not see the possibilities. This again is where the research spirit would count. In many cases the improvement could be made by the department concerned without even referring it to the research department. In other words, it is quite as essential to see the opportunity for improvement as to be able to make it. In fact, the second step cannot be taken without the first, and the first will not be taken unless the knowledge of fundamental science and the habit of analysis, that is, the research spirit, is present at the source.

Thus although industry is beginning to wake up to the importance of science and research, most of our industries have as yet only scratched the ground, and even in those few cases where great research departments have been established, they fall short of the possibilities owing to the lack of the research spirit throughout the engineering staffs of the various departments.

All of this may seem to be a serious reflection upon the teaching profession and in some degree it is; but the fault is shared by the employers of our young engineers. In the early days they criticized the training of the young graduates as too theoretical, and demanded a more practical training. In the attempt to meet this demand, to familiarize the student with the lingo of his profession, to so train him that he would be able to step into a plant and make a good showing the first month, our engineering schools have so seriously slighted or slurred over the fundamentals that the young graduate frequently has no real understanding of the elementary or fundamental phenomena that have to do with his every day work. Our engineering training has never been too theoretical, that cannot be; the real defect is that the student hasn't a sufficiently sound grasp of the theory or science of his profession; if he had he could apply it easily enough, and not according to the machine-like unintelligent method of the real engineer who had made the subject his own and is master of the situation; in short, who has acquired the research spirit and can help to bridge the gap between science and industry.

That this gap needs bridging is hardly open to argument before this audience. There is ample evidence to show that because of this gap, many of our industries are still a generation or two behind the underlying sciences, and that great improvements could be made by the application of available scientific knowledge and of scientific method.

Two things are essential to the advance in industry which every society of this kind was organized to promote: First; The spread of the spirit of research, that is the desire to know the reason why, the habit of scrutinizing evidence of fact, and of clean sure-footed reasoning on the resulting foundation; and second; the extension of our scientific knowledge, that is, a more accurate and more comprehensive knowledge of physical and chemical constants and of the properties of materials.

But the first of these is of prime importance, since success in the second is dependent thereon. Hence my plea to you is for the encouragement and spread of the spirit of research.

TOASTMASTER SAUVEUR: As a professor of metallurgy, I wish that I could claim that the shortcomings which Professor Adams has called to our attention in the teaching of engineering do not apply to the teaching of metallurgy. I feel, however, that we must admit that we come within the field outlined, and we must hope that reforms in the direction which he has indicated will come.

We who are interested in the heat treating of steels realize how much the automobile industry has done to advance the art of treating steels, acting in the nature of a club to their vision and to their encouragement of research. It is therefore fitting that we should have as a speaker a representative of that great industry, and we are fortunate tonight in having with us a man who can talk with authority on any subject pertaining to the construction of automobiles, a man who has contributed much to that field, a man who is instructor of engineering of the University of Michigan, a member of the Naval Advisory Board, and the official representative at this meeting of the Society of Automotive Engineers, Howard E. Coffin, vice president and consulting engineer of the Hudson Motor Car Co., Detroit.

Address of Howard E. Coffin

MR. COFFIN: Mr. Toastmaster, Governor McCray, Members of the Society, ladies and gentlemen: Like most of the rest of you, I suppose, I am a member of a half dozen other engineering organizations, but I have yet to see one of them that, on its third birthday, has been able to put up such a performance as this has been. In looking over the program I see that this is your third banquet. I am wondering what your tenth or eleventh or twelfth will be, if you keep going at this rate. I also notice from the program a happy little selection in the Secretary for a heat treating society, if I am correct in the translation of the name "Eisenman."

I think that if the lantern performs as it should that there will be some very much more interesting things for you than anything that I might say to you, but I cannot help taking a few minutes to just touch perhaps upon one or two things.

The last time I spoke in this room was to a gathering considerably larger than this, as I remember it, in 1916, when some of us were frantically urging that the country prepare for war, even in the face of a political campaign that "he kept us out of war." At that time we were urging an industrial organization for the defense of the country. We were busy, the engineers of the country were busy, particularly those of the five Founders' Societies of the organizations in taking an industrial inventory of the production resources of the country. The steps in this compaign were a survey of the country's producing capacity and its classification and an educational program on the part of the government through the placing of provisional or educational orders throughout the country for munitions, thus building up a nucleus for a munition making capacity; and third, the enrollment of the skilled labor of the country in an industrial reserve.

As you all know, the inventory was taken, legislation was enacted

permitting of the placing of educational orders without the usual legal necessity of a low bid, to the extent of $50,000 each. The program of actual placing of educational orders was about to be launched when we broke off negotiations with Germany, and of course all plans were lost in the chaotic preparation attendant upon our entry into the war.

We had already obtained also the support of the organized labor unions behind the idea of enrollment of the skilled labor of the country in industrial reserve. This program was launched, as you will remember, upon the basis that if this country were to have any continuing form of preparation for defense, it must have as its absolute foundation an industrial organization linked closely with the governmental departments in Washington.

I cannot help touching for a moment upon our actual experience. When war was declared, because of the lack of just such a contact between the war-making machinery of the government and the industrial machinery of the country actually months intervened before contracts were placed by the government for even the most essential articles of war, such items as machine guns, ordnance, rifles, airplanes, and tanks. They were not ordered until from six to nine months after the declaration of war; and as a direct result of another lack of industrial preparedness, if I may use that term, the United States at no time during its participation, the 18 months of its participation in the war, ever supported a single division of an army on the fighting front in any such way that it could have defended itself or inflicted serious loss on an enemy.

That may seem like a pretty serious arraignment of the industrial capacity of a quantity production country, of a country that has prided itself on its ability in quantity production. In fact, General Hahn, in visiting Detroit only a short time ago, and being entertained at breakfast by a group of engineers, made the statement, he having been in Europe practically all of the time, and perhaps not seeing at close range some of the problems on this side, that "You fellows in the industrial side of the job messed things up terribly during the war, but we are organizing the general staff of the army now upon a basis that will prevent this ever being repeated. We are going to train members of the general staff in the various industries of the country and immediately upon declaration of another war, we are going to put the general staff in complete charge of the whole show."

Now if any of you gentlemen had anything to do with those people, with the dyed-in-the-wool army officer, in the early days of the war, I think that your expression will be "My God!" Simply to make a long story short, in connection with the industrial side of the proposition, we learned during the war that it took us about three or four times as long to make a gun with which a man could shoot as it did to teach the man to shoot it. In short, the question of personnel, although we delayed until September before we began to organize an army seriously, some three or four months after we ought to have been equipped, we had two million or more men in France and some other millions in this country pretty well trained and were in position to give a very good account of ourselves insofar as the matter of personnel went. But we were never at any stage of the game during our participation in the war able to give an account of ourselves on the munition producing standpoint, and for just one great reason, or perhaps I had best divide it into two. One

was that on the declaration of war there was no organization or no individual in Washington who had the slightest idea about either what the army needed or how to make it. There were no proper specifications or drawings in existence for practically any article of munition equipment, and it was many times months after contracts were placed before the proper specifications and drawings were supplied to the manufacturer. It was usually other months before the governmental representatives and the industrial men got together as to what the thing ought to look like when it was finished.

Therefore, it seems that the one outstanding lesson of the war ought to be that if we are to have any degree of preparedness,—and, mind you, the very cheapest form of preparedness,—there must be established in peace time a contractural relation between the war-making machinery of the government and the individual manufacturers as the producers of war materials. In short, if the Nordyke & Marmon Co. here in your own city could have in its files a statement from the war department that its equipment had been analyzed and that in the event of war it would be called upon to make, say 6-inch shell cases, and if it could have in its files a complete set of specifications and drawings covering that article, and if in its business department it had a contract, a provisional contract with the government agreeing that within 60 or 90 days after a declaration of war that concern would be producing 2000 of those shell cases per day,—two things would result. In the first place, the Nordyke & Marmon Co. would study the job, they would know what they were going to do, and you can bank on it that there would be a trained nucleus within that organization capable of taking hold of the job upon a moment's notice.

The other thing would be even more important. The moment the contract was placed with the Nordyke & Marmon Co. it would begin to hammer the war department for the specifications and drawings to accompany that contract, and for a full knowledge of the facts as to the tests and treatments which those articles were to go through. In self-defense the war department would be forced to prepare and to keep on hand the specifications and drawings covering this job.

No amount of patriotic oratory, no amount of voting of thumbs by congress in the house or in the senate for a large army or a large navy will ever bridge the first 12 months of the entry of this country into a war. We poured out money like water when we finally got into the war, but we didn't gain one moment of time, and if we are engaged in another war 10 years from now, unless we adopt some continuing system of industrial preparation along the lines that I have outlined, we will pay the same old price in money, time and lives. And we may not have, when that time comes, five or six or eight or ten million other men, or thousands of other factories carrying the load and fighting our fight until we take our time in getting ready.

I was going to talk to you something about the aircraft situation and about the policies of our country and about the necessity for certain legislative action. I will only touch briefly on that. I have here with me some slides and films made in connection with various aircraft activities, particularly the sinking of the German battleships off the Virginia Capes. I think that you would be very much more interested in those, and it will be much more instructive to you than to listen to anything that I might say along any lines of the subject.

I cannot help pointing out to you, however, a few of the things that

have happened. In 1914 the airplane was viewed on the front as a joke. No one had any confidence in its ability to do anything worthy of note in connection with the war. Finally a few observations were made of, for instance, the German column moving through Belgium, by a scattered few French planes. Planes were used once or twice in connection with the battle of the Marne and military leaders began to see the necessities and the possibilities for observation purposes. No one thought of arming or armoring a plane or using it in any other capacity. Finally some bright aviator carried a revolver, then someone took a rifle, someone then mounted a shot gun and then they had a bright idea they could mount a machine gun on a plane. That was in 1914. Planes they were using weighed a couple of thousand pounds. Everyone said that unless they were made as light as air it would be impossible to use them anyway. In 1918, not so very long afterward, they were using planes weighing 30,000 pounds; they were armored, they carried cannon up to approximately 2-inch bore, carried machine guns, four, five or six of them, crews of 8 or 10 men. During the battle of St. Mihiel our General Mitchell was in command of the largest air force ever gathered, made up of Americans, British, French—1500 active planes. They were sending over in flights for attacking the Germans 300 to 350 planes in a flight, dropping thousands of pounds of high explosive, flying low, using machine guns, in every way harrassing the enemy. It is a pretty safe bet if the war had gone on another six months at the rate we were building Liberty engines, at the rate we were supplying them to the Allies, or fitting their planes up, the absolute mastery of the air would have lain with the Allies. In fact, it practically did at the time the armistice was signed, and while the infantry, of course, and the big guns would have gone on hammering the line, there is no doubt at all but that the decisive element in the war would have been the air service.

Now that sounds like a rank heresy, I know, but there have been so many occasions for making statements which have sounded like rank heresy, and then see them come true, that I feel perfectly safe in doing it.

You will remember that it was only about six months ago that a great many people down in Washington were busy explaining that it would be impossible for a battleship, or practically a ship of any kind, to be sunk from the air. I only need point out to you that now these same gentlemen are busy trying to find some way to prevent a battleship being sunk from the air, because it looks as if there is not now, and probably never will again be a battleship built that cannot be sunk from the air. That is just an indication of what we may expect in that line.

The heaviest bombs used in sinking the Ostfriesland which you will see on the films tonight were 2000-pound bombs, about 1000 to 1100 pounds of high explosive and the rest made up of shell casing. The greatest planes that we have now are capable of carrying only one or two of these bombs. Six of them were dropped on the Ostfriesland during the first 19 minutes of the test and although the official reports were given as 24 minutes, we who held our watches on the job know positively it was but 19 minutes before the big battleship of 20,000 tons, and the pride of the German navy, turned turtle and sank. As a matter of fact, only three or four of the bombs were necessary. The others were dropped merely as parting salutes. None of these shells hit the ship. A very canny provision had been introduced into the arrangements to the effect that the air service of the army should be permitted to make

only two direct hits. Consequently, General Mitchell's orders to his fliers were to make no direct hits, in short, to put the bombs in the water alongside the ship, as being the safest and most certain way of sinking her. The results of all the tests off the Virginia Capes have gone to show that an actual hit on an armored ship, with her armored decks, does little more than local damage insofar as removing the anti-aircraft defenses and the personnel are concerned.

As to just what effect these bombs would have upon living personnel on the ship was not, of course, determined in these tests, so this week a repetition of the tests is being made, not only using high explosives, but poison gas shells, with goats and other animals tied in all the various parts of the ship so that between the tests the boards of observation may go aboard and determine the probable effect upon human life.

I can point out to you, too, that although the largest bombs used in these tests were 2000 pounds, a good many of us are invited down on Oct. 8 to see the dropping by the army ordnance department of the 4000-pound bombs. All of the bombing planes used in these recent tests were known as the light bombers. The new heavy bombers will carry two of the 4000 pound bombs.

It is interesting also to know that there is now under construction for the government, planes of as high as 3500 and 3600 horsepower, made up of three groups each of 400-horsepower Liberty engines, geared to propellers nearly 20 feet in diameter. Those of you who heard the talk this morning of the representative of the chemical warfare division and who realize that in the wars of the future poison gas of all the various varieties will probably make a much greater impression and play a much greater part than in the last war, you can see readily what the probable result of these weight carrying craft of the air will be.

I don't want to leave with you the impression that the airplane has spelled the finish of the battleship. That is not true. Our protective plans of the future must be based upon what may be termed a "three plan navy." No fleet can exist in the future without adequate aircraft protection, and, on the other hand, we don't know now of any aircraft activity other than the carrying of planes upon carriers which will themselves need protection of the battleship type; we don't know of any means in the air alone in which we could carry war into distant territory. Airplanes, of course, are limited in their radius. Therefore, we must carry the base with them. The only way to do that is through adequate equipment of aircraft carriers, and the protection of those carriers by the other arms of the naval service. This may bring us, of course, to a greater percentage of high-speed, heavily-armed, but not so heavily armored, cruisers, and it may bring changes in our battleship program. The relation of the capital ship, so-called, the armored ship, to the higher speed cruiser and submarine destroyer, etc., may be changed, but the capital ship will not be entirely eliminated from our program.

The only way, of course, in which the United States can possibly build up an adequate protection in the air is through the development of commercial aviation. The only way that we were able to arrange transport to our troops and for our supplies in the late war, was through a motor car and truck industry which has been built up in peace times through commercial demand. We must do the same thing in the air.

There is one great stumbling block to commercial aviation, exem-

plified by the headlines which you read in the newspapers almost every day. You always see an account at first of airplane accidents; you never see an account of the successful flights. During the last year some 6,000,000 miles have been flown in this country alone, and about 225,000 to 250,000 people transported, and with practically a negligible ratio of serious accidents. But you never hear of those things. You hear only of the terrible accidents.

The one great reason for accidents in this country is that we have dilly-dallied ever since the Armistice, and have not passed one single national law governing our aviators. There is not a law that will prevent any of you from going out and flying anything that you may find in your neighborhood that in any way resembles an airplane. You can go up to 10,000 feet and fly anywhere on earth your heart desires, and there is not a single penalty provided—no provision that the plane must be inspected, no control after it is in the air, and yet if any of you have come up in the elevator tonight you probably noticed the inspection certificate staring you in the face. But if you go up to 10,000 feet and have an accident, no one is blamed, no one is prosecuted, no one inspects the machine or seems to care what happened.

The American Bar Association has been playing with the situation for two years, until it has got to be a favorite indoor sport with them. And they have finally determined that their constitutional limitations will probably prevent the United States government from assuming control of the air. There are many constitutional questions raised,—do you own the property 10 feet above the land you buy, 50 feet, or 5,000 feet, or what is the limit, if any? Moreover, each state is supposed to be jealous of its authority and to resent any action on the part of the federal government to extend its jurisdiction over the state line.

During the last few weeks, I have just heard, as chairman of a committee representing the underwriters of various aircraft interests, of the drafting of a bill which was introduced by Senator Wadsworth in which it is hoped that we will overcome the objections brought up by our more technically advised lawyer friends. We have based this bill upon the provision that while we cannot take control of the air within a state without a constitutional amendment, that the United States government does control the post roads, and every government building and interstate commerce, so we have provided that just so soon as a plane goes into the air and so soon as it crosses over any post road, it becomes amenable to government control. I think that our lawyer friends are almost making up their minds to get behind this bill and push it as a short cut to the desired end. That is the Wadsworth Bill which has just been introduced, and if there is any one thing that you can do to further the cause of aeronautics of this country, it is to push this bid through, creating a department of civil aeronautics within the department of commerce, under Herbert Hoover. Let's get some laws and regulations governing this department and its developments. Canada has done it, and has practically eliminated accidents. She has a large number of air laws within the state. Great Britain has done it, as have France and Italy, and it is up to us to get in line as rapidly as possible.

TOASTMASTER SAUVEUR: I am going to give the floor to Mr. Eisenman for a few minutes as he has a communication to read.

SECRETARY EISENMAN: Mr. Toastmaster, Governor McCray, Mayor Jewett, ladies and gentlemen. The Secretary has upon his desk a

communication from Ferdinand Barnickol, president of the American Drop Forge Association, in which he expresses his regret at his inability to be present tonight and sends his best wishes for the further growth and success of the American Society for Steel Treating. Mr. Barnickol's letter is as follows:

Remarks of Ferdinand Barnickol

After attending one of the meetings of your Society this week, I was impressed with the problems that are common to both your Society and the American Drop Forge Association, which I have the honor to represent, and I was reminded of a story that appeared in a local paper this week.

A president of an Indiana Farm Association was addressing a convention of another organization, and in discussing common problems, he recalled the case of the farmers of an Indiana community, who years ago organized themselves into a secret society, with the slogan—"We plow, we sow, we reap", as the pass words to the lodge room. The lodge room also was used on other nights by a newly fledged Commercial Club. One night a farmer climbed the stairs and spoke through the keyhole: "We plow, we sow, we reap".

"Go to h—l, you Hayseed", bawled out a voice from within. The farmer, abashed, hurried downstairs and told a brother farmer what had happened. The other replied: "Good gracious, this is the Commercial Club's meeting night. You've given away our pass word."

"Oh well", said the farmer, "I got theirs."

So with the American Drop Forge Association. It has learned your Society's pass word and it had nothing but praise for the evidences of useful activity and pronounced accomplishment of your organization. Your president in his opening address at the convention accorded to fellow officers and directors large credit for the effective work which has been done during the past year, but we, who have closely observed the development of the Society, will unstintingly extend to him our congratulations for the able manner in which he has directed his associates with the result that the American Society for Steel Treating has gained more prestige and enduring strength than any organization in the metal or engineering trades, in a similar space of time.

Lt. Col. White has unselfishly devoted his energies toward building up this organization, with the sole desire to gain through education and research, a development far reaching in its beneficial effects wherever steel and other metals are used. The painstaking efforts and the great devotion to his work will make their impress on succeeding administrations, and the foundation he has laid for the future development of the Society's work, will endure for years to come, if the Society on the whole will be guided by the example of Col. White's conception of duty and intelligent endeavor, and if it will keep in mind the fruition of his unselfish enterprise.

I beg to state on behalf of the American Drop Forge Association, that our Association has been a close observer of the American Society for Steel Treating activities, for the forging industry naturally is greatly benefited by the development of the art to which your Society is so ardently devoted, and it feels that the interests of these two organizations are so common, that it wishes to fraternize with you to the fullest

degree, and to lend its support in the further advancement of the principles and ideals, laid down by your able retiring President, Lt. Col. White.

The American Drop Forge Association extends its greetings to the American Society for Steel Treating and congratulates the membership on the faithful support it has extended to its officers as evidenced through the unusually large attendance at your convention this week and the intense interest shown in the convention proceedings.

OBITUARY

DIMITRI KONSTANTINOVITCH TSCHERNOFF, prominent Russian metallurgist and professor, died Jan. 2, 1921, according to an announcement received recently by Col. A. I. Krynitzky, associate physicist of the Bureau of Standards, Washington, and a close friend of the deceased. A brief history of his life has been supplied by Colonel Krynitzky. Professor Tschernoff was born in Petrograd, Russia, Nov. 1, 1839, and received his higher education at the Technologic Institute, later attending the University of Petrograd. In 1866 he entered the employ of the Obouchoff steel plant where steel guns were manufactured. It was in this period of his life when he did the most important work on the heat treatment of steel, its crytallization and metallography. In 1880 he left the Obouchoff plant and went to the south of European Russia where he discovered and developed some rock salt mines, this enterprise bringing him a rather large fortune. He returned to Petrograd in 1884 and after holding several governmental positions, was engaged as professor of metallurgy in the Michael Artillery Academy, where he remained until the Russian Revolution. After spending his vacation in Yalta, Crimea, in 1917, the revolution prevented his return to Petrograd. Overcome by poverty as a result of the existing conditions, his health broke down and he died Jan. 2, 1921. Professor Tschernoff's works in the metallurgical field are well known to students of metallurgy. A good abstract of his most important papers was published in the *Revue de Metallurgie,* 1915, pages 829-62, in commemoration of his seventy-fifth birthday.

THE METALLOGRAPHY OF HIGH SPEED STEEL

By J. P. Gill and L. D. Bowman

FUTURE developments in the quality of high speed steel might be expected not so much in analysis as in methods of manufacture, thus the study of the constitution of high speed steel has become fundamental if the highest quality and most uniform product is to be obtained. How many men have had the experience of two pieces of high speed steel of the same analysis and supposedly of the same heat treatment, where one piece gave results much better than the other on the same job? Why? Surely there is a reason. And that reason undoubtedly is enclosed in the history of those pieces of steel, for it is their history that determines their quality; and a study of their history is a study of their constitution.

The use of the words "high speed steel" in this paper refer to a steel of an approximate analysis as follows:

	Per cent
Carbon	0.65—0.70
Tungsten	17.50—18.50
Chrome	3.75— 4.15
Vanadium	0.90— 1.25

This analysis is recognized as the analysis of the first quality high speed steels. Moreover, when reference is made to the ingot or billet, etc., it infers high speed steel.

The word metallography used in the title of this paper, "The Metallography of High Speed Steel" is used in its broader sense; under this title we are including the critical points and constitution of high speed steel with a discussion of whatever experiments and factors that bear a direct relation to these two subjects.

There have been but few systematic investigations made on the subject of the constitution of high speed steel, although there has been a reasonably large number of investigations made on the transformation points, the hardening and drawing temperatures, efficiencies of various analysis, uses, magnetic properties, etc. A paper presented by Honda and Murakami[1] at the Iron and Steel Institute, in May, 1920, represents probably the best that has been written on the constitution of high speed steel and is worthy of consideration in detail, but some of the statements they make are but feebly supported by the evidence they present. Their experiments consisted essentially of a study of three series of high speed steels, the first in which the percentages of tungsten and chromium were constant with the percentage of carbon as a variable, the second with the percentages of tungsten and carbon constant with the percentage of chromium as a variable, and the third with the percentages of chromium and carbon constant with the percentage of tungsten as a variable. Honda has deduced most of his changes in structure in heating and cooling by magnetic analysis. A steel containing 0.62 per cent carbon, 5.12 per cent chromium and 17.20 per cent tungsten is taken as a typical example and in the normal condition he states that this steel is composed

1. Journal Iron and Steel Institute, 1920, No. 1, Vol. CI, p. 647.

A paper presented at the Indianapolis Convention. The authors, J. P. Gill and L. D. Bowman, are metallurgists, Vanadium-Alloys Steel Co., Latrobe, Pa.

of iron-dissolving tungstide, free tungstide, chromium carbide and tungsten carbide all in a free state.

Here is shown the manner in which they would write this structural constitution:

$$[(Fe) + (Fe_2W)] + [Fe_2W] + [Cr_4C] + [WC] \quad (1)$$

Above the Ac1-3 point both carbides dissolve in the austenite and then the constitution is thus:

$$[Fe_2W] + [(Fe) + (Fe_2W) + (Cr_4C) + (WC)] \quad (2)$$

The constituents in solid solution are enclosed by parenthesis and those in a free state by brackets. As the temperature increases above the Ac1 point, the chromium carbide dissociates as follows:

$$2Cr_4C = Cr_3C_4 + 5Cr \quad (3)$$

Then as the affinity of carbon for chromium seems to be stronger than its affinity for tungsten, some of the chromium produced by the dissociation of Cr_4C will react on the tungsten carbide as follows:

$$3Cr + 2WC + 4Fe = Cr_3C_2 + 2Fe_2W \quad (4)$$

hence at the higher temperatures the structure is

$$[Fe_2W] + [(Fe) + (Fe_2W) + (Cr) = (Cr_3C_2) + (WC)] \quad (5)$$

But cooling from the temperature at which this structure exists, the lowering of the transformation point is caused by the presence of dissolved carbide Cr_3C_2 in austenite containing chromium and tungstide, thus the steel cooled to normal temperatures has the same constitutional structure that existed at the high temperatures, that is

$$[Fe_2W] + [(Fe) + (Fe_2W) + (Cr) = (Cr_3C_2) + (WC)] \quad (5)$$

If the steel be now heated again the dissolved carbides separate and the reactions (3) and (4) proceed from right to left and (Cr_4C) and WC are again formed.

To substantiate these views, Honda says further: "First, in the magnetic analysis, the chromium effects the lowering of transformation in the presence of carbon, and if the carbon content is 0.6 per cent, about 3 per cent of chromium is sufficient for the lowering or the self-hardening; a further addition of chromium not being effective, unless the carbon content is increased. Second, the resistance to tempering of hardened steels depends on dissolved Cr_3C_2 and tungstide in iron containing chromium as in the steels of Series II where the percentages of chromium is the variable; as the percentage of chromium increases to 3.32 per cent, the maximum increase of magnetization at the range of 400 degrees Cent. gradually decreases and that of 700 degrees Cent. increases, but a further increase of chromium has no effect. While in steels of Series I, with the percentage of carbon as a variable, as the carbon content increases from 0.57 to 1 per cent, the maximum increase of magnetization at 700 degrees Cent. becomes less, showing that the resistance to tempering increases. Third, that the maximum increase of magnetization at about 700 degrees Cent. due to tempering at first increases as the maximum temperature of previous heating increases from Ac1 point to 1000 degrees Cent., but decreases as the temperature further increases. This would show that if the maximum temperature of previous heating is below 1000 degrees Cent., the quantity of the dissolved carbide Cr_3C_2 is very small and slowly increases with the rise in temperature and thus by tempering, the separation of the carbide slowly increases. Fourth, that in chromium steels without tungsten there exists at high temperatures some dissociated chromium and Cr_3C_2 as shown by the lowering of the transformation by a quick cooling from 900 degrees Cent., but as tungsten is added to the steel some tungstide is formed

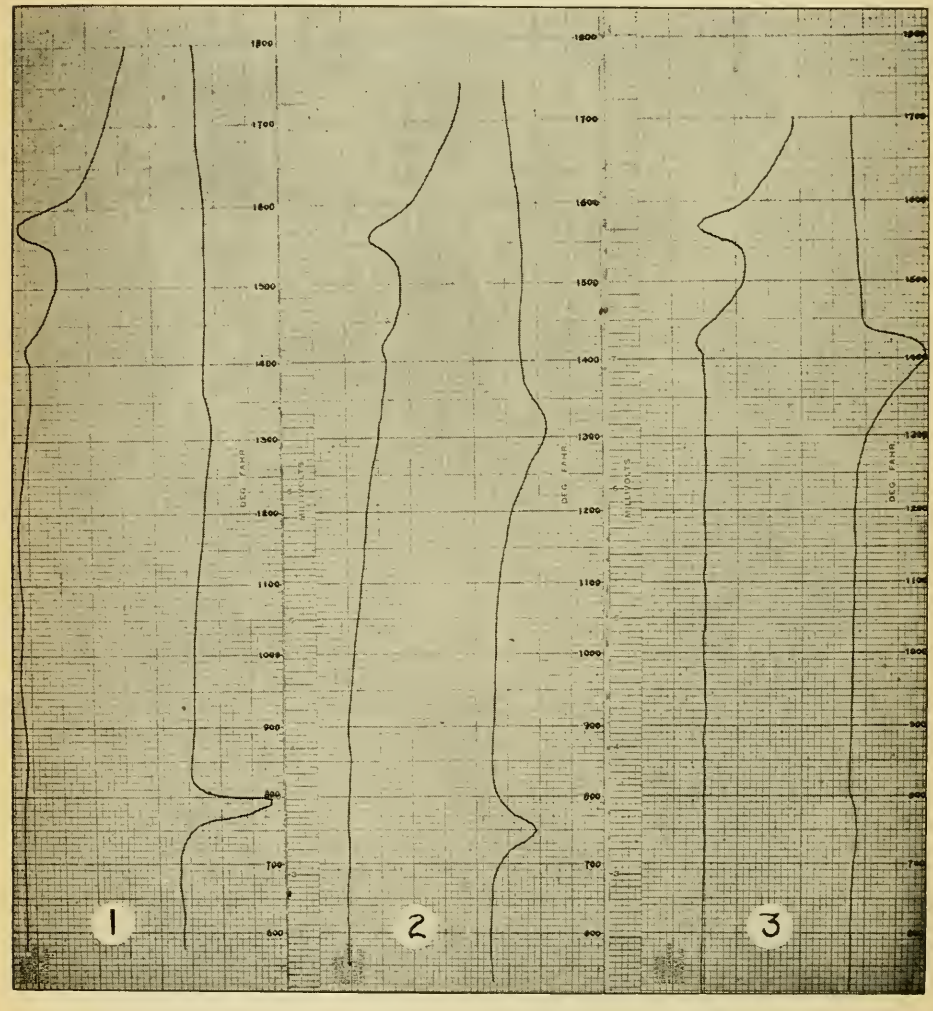
and this tungstide seems to prevent the recombination of chromium and Cr_3C_2 thus causing the lowering of the transformation."

Reference will be made to this theory later; however, it is interesting to note here that the results given have been deduced nearly altogether from magnetic analysis.

Edwards and Kikkawa[2] briefly discussed the constitution of high speed steels in a paper before the Iron and Steel Institute in 1915, but they made no attempts to give exact chemical composition of the constituents. Professor Arnold[3] studied the constituents of high speed steels by analyses of residues and his paper presented also before the Iron and Steel Institute in 1919 is highly interesting.

Other papers by Honda and Murakami[4] and by Hultgren[5] on tung-

2. Journal Iron and Steel Institute, 1915, page 6
3. Journal Iron and Steel Institute, 1919.
4. Revue de Metallurgie, January, 1920. p. 37.
5. Metallographic Study of Tungsten Steels. J. Wiley & Sons, 1920.



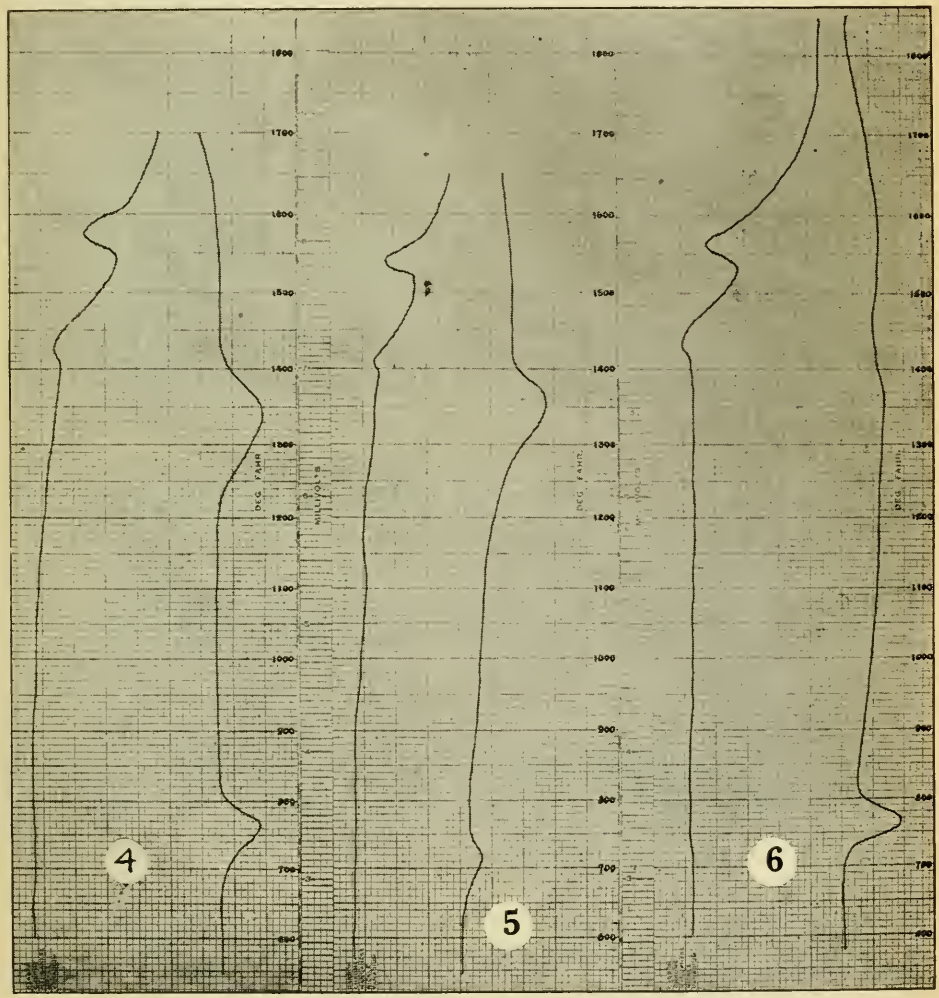
Figs. 1-3—Heating and cooling curves of high speed steel. Points derived by differential method

sten steels lend an interesting aspect to the constitution of high speed steel. Papers by Carpenter[6], Yatsevich[7], and Andrew and Green[8] fully discuss the critical points in high speed steel, while a large number of other investigators have likewise contributed to the knowledge of this phase of high speed steels.

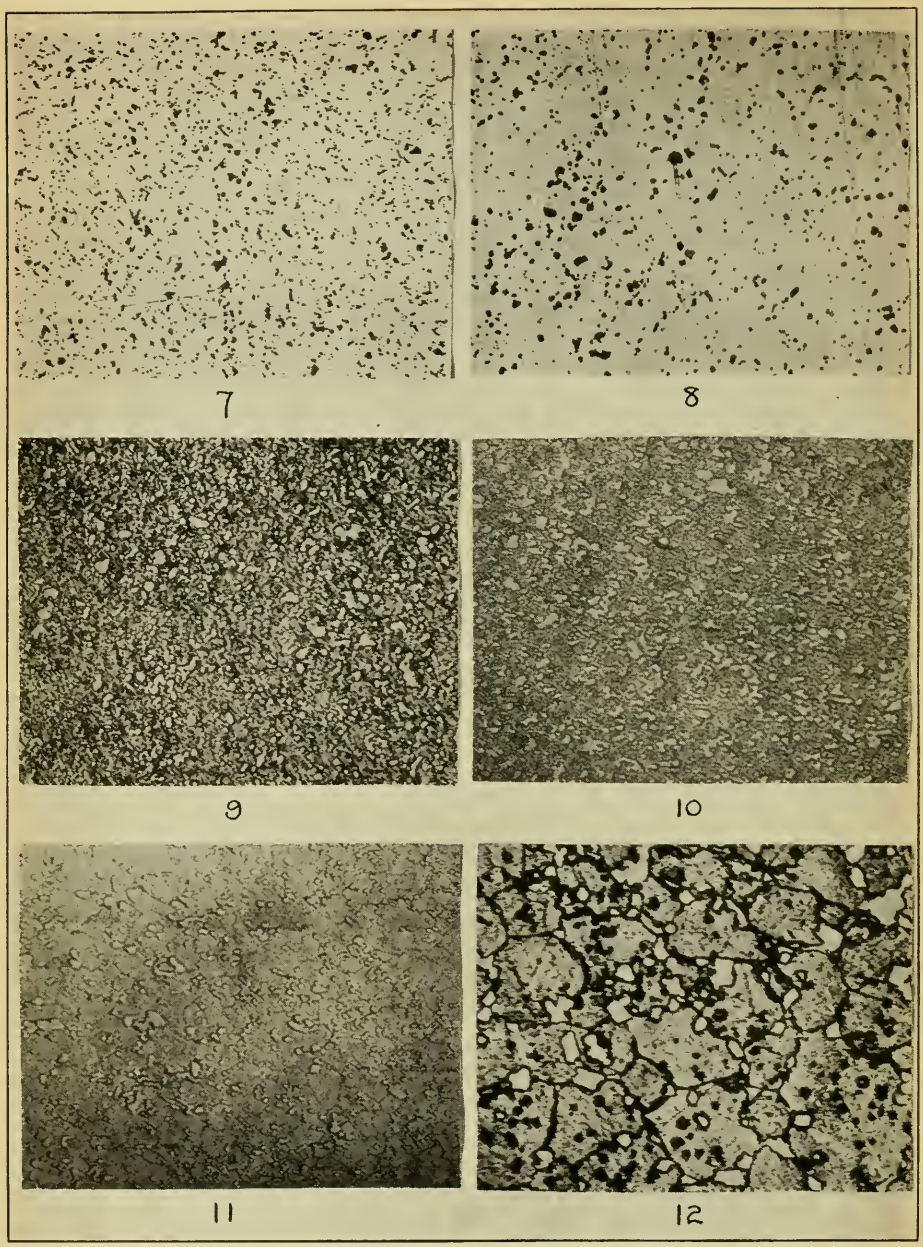
In presenting this paper we have found it necessary to group our experiments under a number of headings. These headings will be taken up not in the order of their importance, but in such an order that we believe will prove the clearest.

Critical Points—A number of heating and cooling curves have been made, a few of which are reproduced in Figs. 1-6. These points were derived by using the differential method. The rate of heating and cool-

6. Journal Iron and Steel Institute, 1902. p. 433; 1906, p. 377.
7. Revue de Metallurgie, 1918. p. 65.
8. Journal Iron and Steel Institute, 1919. p. 305.



Figs. 4-6—Heating and cooling curves of high speed steel. Points derived by differential method



Figs. 7-8—High speed steel showing tungstides going into solution. Fig. 7 was quenched at 2100 degrees Fahr. and Fig. 8 at 2380 degrees Fahr. Etched in sodium hydroxide—hydrogen peroxide and X250 Figs. 9-10—Micrographs showing advantage of picric acid over nitric acid as etching reagent. Fig. 9—Etched with picric acid; Fig. 10, with nitric acid. Both X500. Figs. 11-12—Hardened high speed steel specimens etched with alcoholic solution of nitric acid. Both X500

ing was practically the same for all the specimens. The steel used in obtaining the curves was in the annealed state and had an analysis as follows:

	Per cent
Carbon	0.69
Silicon	0.23
Manganese	0.29
Sulphur	0.008
Phosphorus	0.018
Tungsten	18.55
Chromium	3.82
Vanadium	1.01

It will be noticed in all the heating curves that there are distinct decalescence points beginning at a temperature of about 1400 and 1530 degrees Fahr. and reaching a maximum respectively at the temperatures of 1420 and 1570 degrees Fahr. The upper of the two points begins considerably more intensely than the lower, and is also more prolonged. These points are extremely constant, and Sauveur[9] has suggested that since the two points occur within such narrow limits it is possible that they do not indicate two distinct transformations but represent two phases or stages of the same transformation. This view seems untenable since if the two points represented two phases of the same transformation, a change in the heating rate would alter the constancy of the positions in which they occur; also if the heating was stopped between the two points the transformation already begun would be likely to go to completion by holding the temperature; this however is not the case. In Fig. 3 heating was stopped at 1700 degrees Fahr. and the temperature was allowed to fall immediately, the rate of cooling being marked on the diagram. A distinct recalescence takes place beginning at 1420 degrees Fahr. and reaching a maximum at 1370 degrees Fahr. while at 790 degrees Fahr. another feeble decalescence point may be discerned that likely would remain unnoticed if it were not for the other diagrams that develop this point so clearly. In Fig. 2 heating was stopped at 1750 degrees Fahr. and cooling allowed to commence at once. The two recalescence points seem to be of about the same intensity at their maximum but the higher point is much more prolonged.

In Fig. 1 where the heating was stopped at 1800 degrees Fahr., the upper point is barely noticeable while the lower point is intense. In Fig. 6, heating was stopped at 1850 degrees Fahr. and the curve thus developed is practically the same as in Fig. 1, where the heating was stopped at 1800 degrees Fahr. In Fig. 5 the heating was stopped at 1650 degrees Fahr. but the specimen was held at this temperature for 30 minutes before cooling started. Two distinct points are noticeable, while in Fig. 3 the lower point can barely be noticed yet the specimen was heated to a temperature 50 degrees higher. In Fig. 4 the temperature was likewise held for 30 minutes this time at a temperature of 1700 degrees Fahr. and the two recalescence points have about the same maximum intensity. This curve corresponds closely to Fig. 2 where the maximum temperature reached was 1750 degrees Fahr. The rate of heating and cooling the specimen was practically the same in producing each curve.

It will be noticed that the two recalescence points remain fairly constant and as one is suppressed the other is intensified, indicating two

The Metallography and Heat Treatment of Iron and Steel, Sauveur & Bolyston, 1918.

distinct points, and not the shifting of one point to another position. The transformation taking place therefore at the upper decalescence point apparently does not go to completion upon reaching the temperature at which the point is indicated on the diagram but depends upon the temperature reached above this point and the time held at this temperature. This is further substantiated by the prolonging of the point after the maximum has been passed.

The first decalescence point thus seems to result from the carbon contained in the sorbite going into solution or the formation of austenite, while the upper decalescence point results from the commencing of the solution of the tungstides which depends upon time and temperature for completeness, in proof of which are shown two micrographs, Figs. 7 and 8, of the same piece of high speed steel, Fig. 7 of which was quenched from 2100 degrees Fahr., and the other from 2380 degrees Fahr. A comparison shows how much more completely the tungstides have gone into solution in the specimen quenched from the higher temperature.

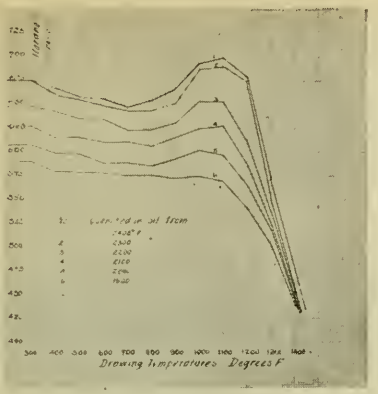
The recalescence points do not permit of as easy an explanation. It is feasible, however, that the upper point represents the transformation of the austenite, and the lower point the forming of the tungstides from solution. This is the reverse of what is expected in most steels where the last transformation to take place on heating is the first transformation to take place on cooling. Yet, as shown by the curves, as the upper recalescence point is suppressed, the lower point is intensified, and as the lower point is intensified more tungstides have been dissolved either by heating to a higher temperature or by holding at a temperature above the upper decalescence point. It would then seem that as the tungstides went into solution the transformation of the austenite would be retarded and the upper recalescence point would occur at a lower temperature, but here it is actually suppressed more and more by the solution of the tungstides until no point exists. As the solution of tungstides becomes greater the lower decalescence point increases in intensity indicating a direct relationship, or that the lower point is where the tungstides form from solution.

Secondary Hardness—Bearing more or less direct relation to the critical points of high speed steel is what is termed "the phenomenon of secondary hardness" which we do not consider a phenomenon at all, but a natural occurrence. Howard Scott[10] classified a number of quenched specimens into two groups, one of which exhibits secondary hardness and which were quenched from a temperature above 2000 degrees Fahr. and the other which did not exhibit secondary hardness and which were quenched from a temperature less than 2000 degrees Fahr. Fig. 13 shows a chart which bears out his classification very well.

A microexamination of a number of specimens shows that the secondary hardness increases in a direct proportion to austenization. So it is well that consideration be given here to the effect of the different elements on secondary hardness or in truth on austenization.

A carbon steel containing 1.10 per cent carbon may be hardened by quenching in water from 50 degrees above its critical point to obtain a Brinell hardness of nearly 700, yet it does not show a secondary hardness on tempering, and its structure is plainly martensitic. A steel containing 0.97 per cent carbon and 4.05 per cent chromium with no

10. Scientific Paper No. 395, Bureau of Standards.



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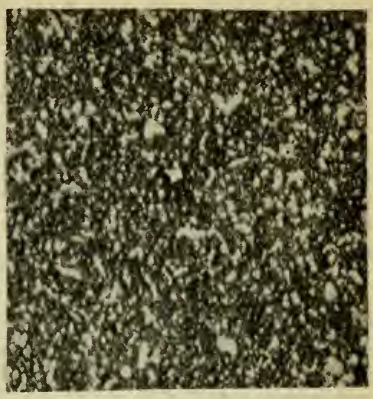

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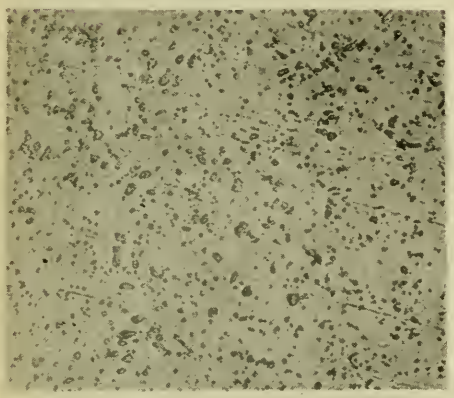

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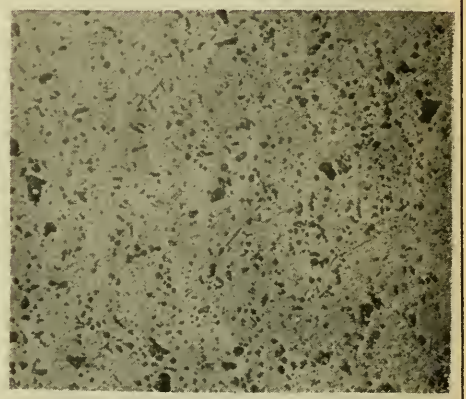

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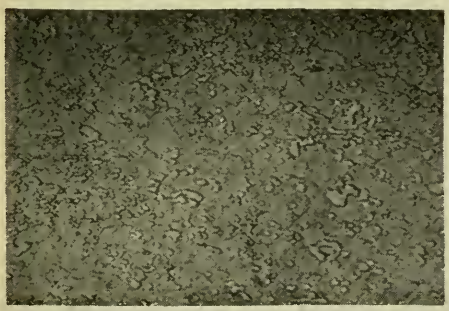

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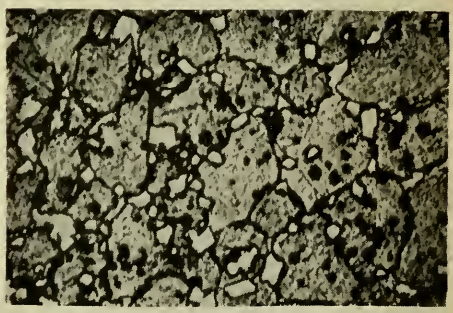

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Fig. 13—Chart showing classifications as to secondary hardness. Fig. 14—Heat tinted specimen showing development of structure although not as clearly defined as when picric acid is used. X500. Fig. 15—A specimen etched with sodium hydroxide—hydrogen peroxide. X500. Fig. 16—A specimen etched with potassium hydroxide and K_3 Fe $(CN)_6$ X500. Figs. 17-18—Micrographs of hardened high speed steel showing polyhedral structure Etched in nitric acid and X500

tungsten can be hardened in air from 1650 degrees Fahr. and will exhibit extreme hardness if quenched in oil but such a steel does not show a perceptible secondary hardness and a microexamination of the hardened steel shows a martensitic structure. Moreover, in making cooling curves of a steel with a variable chromium content, the maximum temperature from which cooling begins, does not have an appreciable influence on the position of the recalescence points.

A steel containing 0.68 per cent carbon and 15 per cent tungsten when quenched in oil from 2000 degrees Cent. shows only a hardness of about 500 Brinell but does exhibit a slight secondary hardness. How-

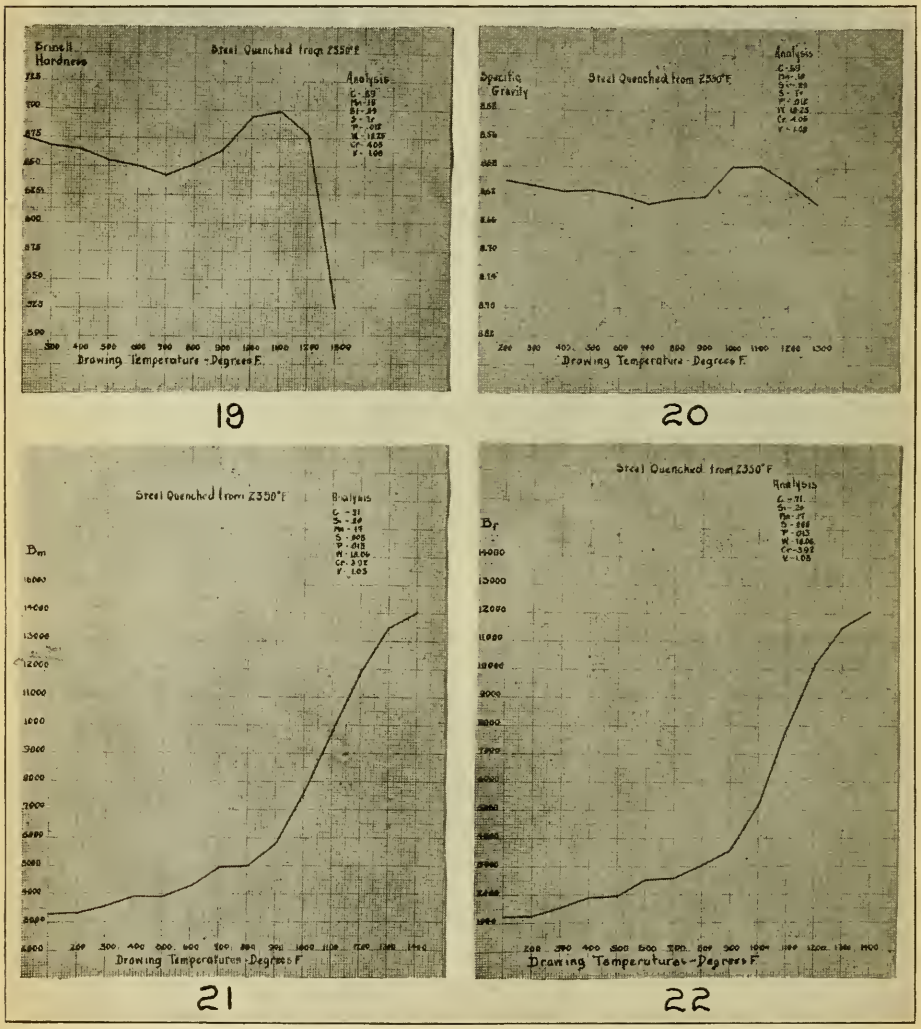


Fig. 19—Curve showing hardness of austenite as compared with martensite. Fig. 20—Curve showing specific gravity of austenite as compared with martensite. Fig. 21—Curve showing changes in maximum magnetic induction by drawing hardened high speed steel. Fig. 22—Curve showing changes in residual magnetic induction by drawing hardened high speed steel

ever in such a steel most of the tungstides remain undissolved regardless of the temperature from which quenching takes place. The temperature from which cooling curves are made on such a steel does influence the position of the recalescence points. Thus it is a combination of the three elements—carbon, chromium and tungsten—not one nor a combination of two, that depress the critical range to such a degree that an austenitic steel can be produced by practical heat treating methods, which being tempered to the harder constituent martensite produces secondary hardness. It is a natural result, and seems unusual only since austenite is not produced in most steels by commercial heat treatment.

Etching Reagents—A number of etching reagents have been used for the development of the microstructure of high speed steels with various results. An alcoholic solution containing from 1 to 4 per cent nitric acid has been used on annealed or hardened and highly drawn specimens. A 4 per cent solution reacting on annealed specimens requires only some 30 to 40 seconds to fully develop the structure, while the same solution reacting on a hardened and highly drawn specimen requires from 1½ to 3 minutes to develop the structure. We have not found, however, nitric acid as valuable an etching reagent for annealed specimens as an alcoholic solution diluted with from 10 to 15 per cent water and saturated with picric acid. This solution develops the matrix in greater detail than does nitric acid as shown by Figs. 9 and 10.

Neither of the two reagents color the tungstides and they remain clearly revealed as white embedded globules. On specimens hardened and not drawn an alcoholic solution containing from 6 to 8 per cent nitric acid reacting on the specimen from 3 to 6 minutes will clearly develop the polygonal structure that is characteristic of hardened high speed steel, while on specimens of this type picric acid reacts exceedingly slow, and even after an immersion of an hour the structure is but faintly developed. Figs. 11 and 12 are of hardened specimens etched with an alcoholic solution of nitric acid.

An alcoholic solution containing from 2 to 5 per cent nitric acid and saturated with picric acid does not develop the structure of annealed specimens as well as the picric acid alone, and seems to offer no advantage in the etching of the hardened specimens over a nitric acid solution. It is readily apparent when using these etching reagents that the time required for the development of the structure is a direct indication of the heat treatment the steel has received, and many times valuable information can be obtained concerning the treatment of the steel by timing the etching.

Heat tinting will develop the structure of annealed specimens as the result of a thin coat of iron oxide forming over the matrix while the embedded tungstides remain unchanged. This is shown by Fig. 14. We have not found any advantage in using this method for the development of the microstructure, as the matrix is not as clearly defined as when using picric acid.

A solution made up of 30 per cent commercial hydrogen peroxide and 10 per cent sodium hydroxide and the remainder water, proved valuable for etching the tungstides a dark brown and black while leaving the matrix apparently unetched. This solution works equally well on all specimens, regardless of the condition in which they exist. It is necessary however, to make up the solution shortly before using as it

disintegrates rapidly and loses its strength. A specimen etched with this solution is shown by Fig. 15. The etching time is from 10 to 15 minutes and as only the tungstides are etched the time remains the same on all specimens regardless of their heat treatment.

Another solution from which etching results can be obtained quite similar to the solution just mentioned is made up of 10 grams potassium or sodium hydroxide and 10 grams $K_3Fe(CN)_6$ in 100 cubic centimeters of water. Practically the same results were obtained by using this solution as the sodium hydroxide-hydrogen peroxide solution. This solution will etch the tungstides much more rapidly, as the etching time is only from 30 to 50 seconds. Another advantage this solution has over the sodium peroxide solution is its stableness, as it may be preserved for three or four months without apparent decomposition. A specimen etched with this solution is shown in Fig. 16.

Nomenclature—The question of nomenclature of the constituents of high speed steel other than the tungstides or carbides often arises, and you have probably asked yourself whether or not the nomenclature of the constituents of a carbon steel are applicable to a steel that is really approaching an alloy for 25 per cent of the composition of high speed is not iron. From evidence that follows and considering the broadness of the definitions of the nomenclature of the constituents of carbon steel, we believe that the same nomenclature is applicable to the constituents of high speed steel.

Austenite as it is defined is the solid solution of iron and carbon as it exists above the transformation range or as preserved at lower temperatures by rapid cooling or by the presence of retarding elements. It may contain carbon up to the saturation point, namely 1.7 per cent carbon. It is polyhedral and is darkened less by the acid etching reagents than troostite, sorbite and martensite. Its hardness is variable depending on the state in which it is preserved, but is usually never considered as hard as martensite. It is slightly magnetic and does not show as great a volume change in passing from pearlite or sorbite into austenite, as does martensite. Considering the austenite of high speed steel, it is primarily a solid solution of iron and carbon plus dissolved tungsten, chromium and vanadium. That it is polyhedral is evidenced by any micrograph of hardened high speed and is shown here by Figs. 17 and 18.

That it is darkened less by the acid reagents than are martensite, troostite and sorbite is shown by the etching time necessary for etching steels containing these constituents and previously mentioned. Its hardness is not as great as that of martensite as shown by the diagram in Fig. 19. That it occupies a smaller volume than does martensite is evidenced by this diagram in Fig. 20 of the change in specific gravity by drawing hardened high speed steel. The austenite of high speed steel is also feebly magnetic, and in Figs. 21 and 22 are two diagrams showing the changes produced in hardened high speed steel in maximum and residual magnetic induction by drawing.

Next, considering martensite which is defined as the first stage in the transformation of austenite characterized by needle-like structure and great hardness. Its hardness exceeds that of any other constituent produced in the transformation of austenite with pearlite. It is magnetic. It etches darker with acid reagents than austenite but lighter than troostite. It represents a metastable condition in which the steel is

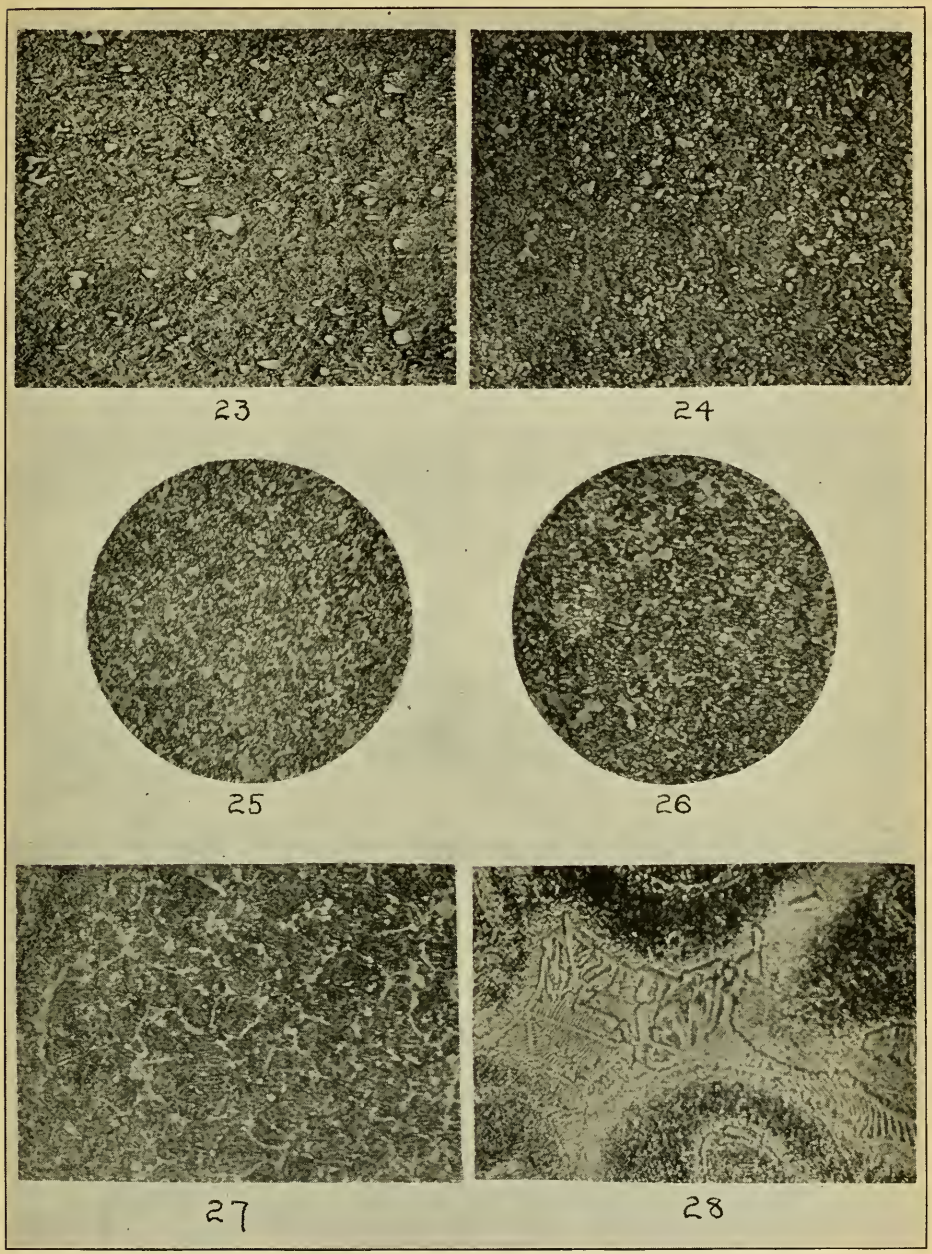
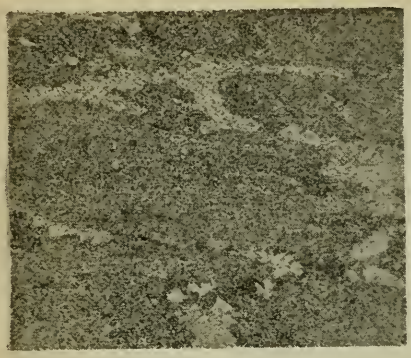


Fig. 23—Martensite as developed in high speed steel. Etched with nitric acid and X500. Fig. 24—Sorbite as developed in high speed steel. Etched with picric acid and X500. Fig. 25—Annealed high speed steel of 228 Brinell hardness. Fig. 26—Hardened high speed steel drawn to 1450 degrees Fahr. and of 444 Brinell hardness. Both Figs. 25 and 26 were etched with picric acid and X500 and show difficulty in distinguishing troostite. Fig. 27—Micrograph showing coalescence of imbedded globules. Etched with nitric acid and X500. Fig. 28—Globules in an ingot representing a single eutectic mixture. Etched with nitric acid and X1100



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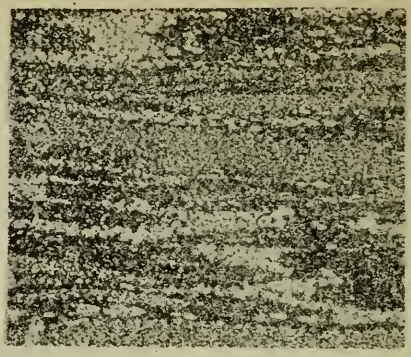

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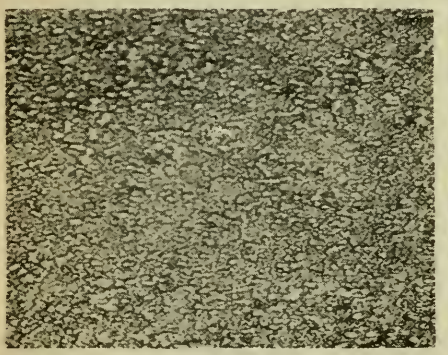

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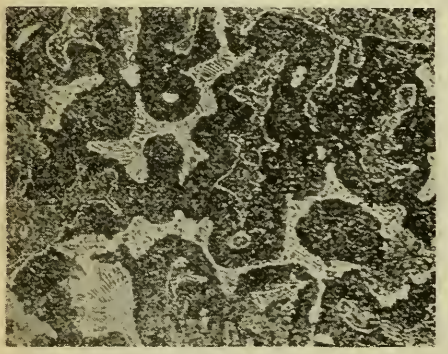

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Fig. 29—As working of ingot begins eutectic mixture of globules breaks up. Etched with nitric acid and X275. Fig. 30—Elongation of globules into stringers caused by further working of ingot in same direction. Etched with nitric acid and X275. Fig. 31—Characteristic distribution of globules after upsetting or further reduction of ingot. Etched with nitric acid and X500. Fig. 32—Structure of high speed steel ingot as cast. Etched with nitric acid and X200. Fig. 23—Upon annealing the ingot only two constituents are noticeable. Etched with nitric acid and X500. Fig. 34—Structure represented by etching specimen in Fig. 33 with sodium hydroxide—hydrogen peroxide. X1100

caught during retarded transformation as austenite is passing into a mixture of ferrite and cementite.

Comparing the martensite as developed in high speed steel, Fig. 23, it is certainly the first stage in the transformation of austenite, as characterized by its increasing hardness, greater volume, and considerably higher values for residual and maximum magnetic induction. It is likewise distinguished by its needle-like structure and high speed steel existing in the martensitic state is in its hardest state. It etches darker than austenite but does not etch as rapidly as troostite or sorbite. That it represents a metastable condition is evident, since by quenching high speed steel from a high temperature austenite is produced which can be readily changed into martensite by heating to 1100 degrees Fahr., while heating to a higher temperature destroys the martensite.

Considering next in order, troostite, it is defined as the stage in the transformation of austenite that follows martensite and precedes sorbite. That it is an uncoagulated conglomerate, and that the degree of completeness of the transformation it represents is not definitely known and probably varies widely. It is not always easily and definitely discernible under the microscope, as it occurs in an irregular manner. Acid etching reagents darken it more than martensite or sorbite, one or both of which usually accompany it. Its hardness is intermediate and its magnetic properties are indefinite.

Troostite as it should exist in high speed steel is the most indefinite of the constituents in the transformation of austenite. Under the microscope it is exceedingly difficult to distinguish and two micrographs, Figs. 25 and 26, bear evidence of this fact. Fig. 25 is of annealed high speed steel having a Brinell hardness of 228, while Fig. 26 is of hardened high speed steel drawn to 1450 degrees Fahr. and has a Brinell hardness of 444. There is practically no difference in the appearance of the matrix. This micrograph of the specimen drawn to 1450 degrees Fahr. was chosen as representative of the microstructure that apparently exists after the disappearance of the martensite. This structure can hardly be called sorbite, as sorbite in high speed steel represents a stable condition, while the physical and magnetic properties co-existing with this structure vary to a great degree as a result of heat treatment. Its properties are intermediate as are the properties of troostite in carbon steel. Acid etching reagents, however, apparently darken it to about the same degree as sorbite in high speed steel. That it represents a step in the transformation of austenite is apparent from its physical and magnetic properties which are intermediate. Thus even though microscopically troostite cannot be satisfactorily distinguished, in view of the broadness of the definition of the term, there is justification of giving the name troostite to that structure that exists between martensite and stable sorbite.

Sorbite as defined is the stage in the transformation of austenite following troostite and preceding pearlite. It is usually considered as an uncoagulated conglomerate of pearlite with ferrite or cementite depending on the carbon content of the steel, but that it may contain some incompletely transformed matter. It is not resolvable under the microscope and cannot properly be represented on the equilibrium diagram, hence it represents a metastable condition. Considering the sorbite of high speed steel as shown by micrograph, Fig. 24, it follows troostite as we have so considered it in the transformation of austenite. It is not resolvable under the microscope. It represents a stable condition and in this respect resembles the pearlite of carbon steel, and would

therefore be represented on the equilibrium diagram below Ac_1. This is evidenced by the fact that a resolvable constituent of high speed steel similar microscopically to the pearlite of carbon steel is not to be obtained. Regardless of the treatment that may be given to high speed steel, sorbite apparently represents the end in the transformation of the austenite, thus becoming a stable constituent and deserving of representation on the constitutional diagram where the pearlite is represented in carbon steels. The pearlite of carbon steels partly corresponds to the sorbite of high speed steel as just mentioned, and not bearing a true resemblance to any constituent in high speed steel will not be described.

Imbedded Globules—The chemical composition of the matrix and of the embedded globules of high speed steel in its different states presents an interesting study that few investigators have attempted. Honda's[1] theory that in the annealed condition high speed steel was composed of iron-dissolving tungstide, free tungstide, chromium carbide and tungsten carbide is difficult of conception in view of some of the following evidence.

Every manner of etching the specimen that has been tried results in all the globules having exactly the same appearance, while if the globules were of different composition it seems that some of the various manners of etching would have attacked them differently. Second, from preliminary observations the melting points of Fe_2W, Cr_4C and WC vary widely; we may then assume that their rate of absorption or solution by the iron-dissolving tungstide would vary likewise; yet neither thermal nor magnetic curves reveal critical points that indicate a differential solution of the globules. Third, when high speed steel is heated to a temperature approaching its melting point there is a distinct coalescence of the embedded particles which structure becomes normal and can only be obliterated by quenching from exceeding high temperatures. This structure is shown by Fig. 27. This mixture of the globules behaves in exactly the same manner as before they coalesced; that is, it etches similarly and does not affect the critical points; thus if before coalescing the globules had been of different compositions we would expect that after mixing they would either etch differently or affect the critical points. Fourth, in tracing the history of the formation of the globules from the ingot we find that in the ingot they represent a single eutectic mixture which will be considered later and is here shown by Fig. 28. This formation by working begins to break up as shown in Fig. 29, and by further working in the same direction will become elongated into stringers as shown by Fig. 30, and finally by upsetting or by further reduction take the characteristic distribution as shown here by Fig. 31. If then the globules were of different composition there seems to be no place in the history of the steel that allows for their formation.

Professor J. O. Arnold[11] isolated and analyzed a number of tungstide residues from high speed steel of varying analyses. His results are quite interesting and here is given one analysis of a high speed steel he used and the analysis of the residue obtained:

	Per cent
Carbon	0.55
Chromium	2.62
Tungsten	15.92
Vanadium	1.16
Silicon	0.34
Sulphur	0.058
Phosphorus	0.017
Manganese	0.20

1. Journal Iron and Steel Institute, 1919.

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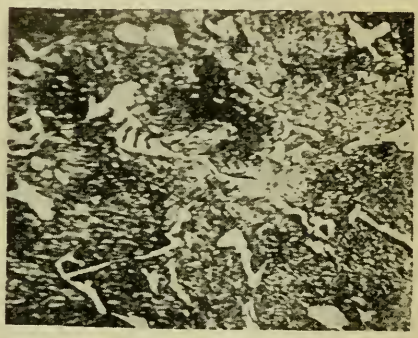

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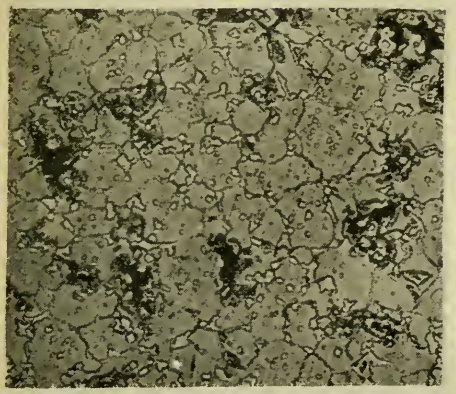

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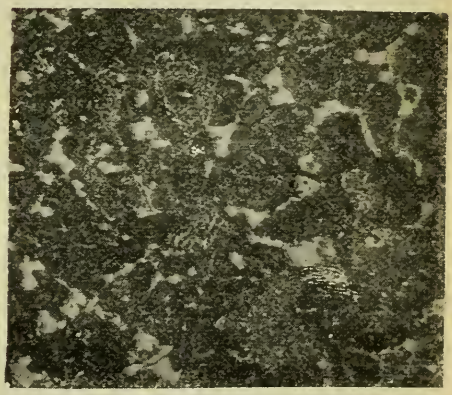

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Fig. 35—Structure developed in high speed steel by hardening from temperature at which actual fusion of the tungstide takes place. Etched with nitric acid and X1100. Note similarity to ingot as cast, Fig. 32. Fig. 36—Structure of specimen, Fig. 35, after etching with sodium hydroxide—hydrogen peroxide. X1100. Figs. 37-38—Micrographs taken along a bar, one end of which was held at room temperature while the other was melted. Etched with nitric acid and X500. Fig. 39—Black areas representing an actual fusion of the tungstide. Etched with nitric acid and X500. Fig. 40—Annealed specimen, the small faint areas of the tungstide being the same as the black areas in Fig. 39. Etched with nitric acid and X500

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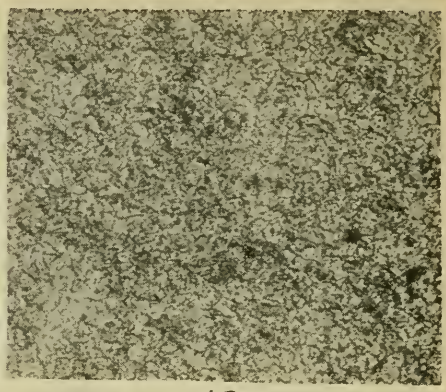

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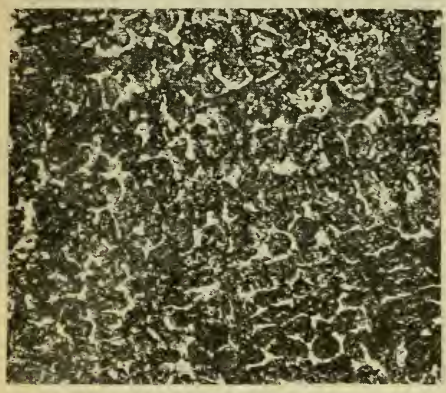

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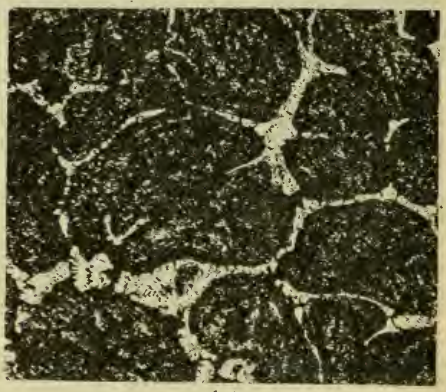

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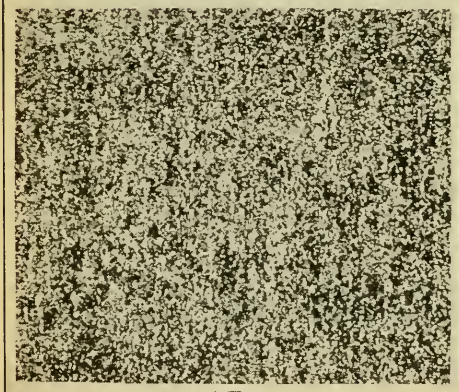

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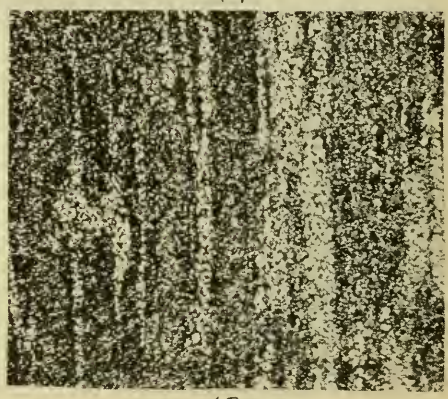

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Figs. 41-42—Micrographs in which no carbides of chromium can be distinguished and which have appearance of a perfect solution of the chromium. Etched with nitric acid and X500. Figs. 43-44—Micrographs showing distribution of tungstides. Fig. 43 taken ⅛ inch from outside of ingot and Fig. 44 taken 2½ inches from outside of same ingot. Etched with nitric acid and X500. Fig. 45—Micrograph of specimen rolled from 1½ inch square cut from outside of 7-inch ingot. Etched with nitric acid and X500. Fig. 46—Micrograph of specimen rolled from 1½-inch square cut from center of same ingot. Etched with nitric acid and X500

Weight steel dissolved Grams	Weight of residue obtained Grams	Carbon Per cent	Iron Per cent	Chromium Per cent	Tungsten Per cent	Vanadium Per cent
8.7718	2.0144	2.33	23.96	3.13	64.24	4.68
8.9466	2.0426	2.32	23.62	3.13	64.24	4.81

It will be noticed from the above analysis that a proportionally greater percentage of the tungsten is contained in the residue obtained. Thus it would be expected that an increase in the tungsten content would increase the quantity of the globules and this has been confirmed by an examination of a number of high speed steels containing tungsten in varying percentages. Also we have found as did Honda and Murakami[1] that an increase in the percentage of carbon or chromium with the tungsten content remaining the same did not noticeably increase the quantity of the globules. We have also etched a number of specimens of ferro-tungsten containing less than 0.20 per cent carbon and from 65 to 80 per cent tungsten and found that the sodium-peroxide and ferricyanide reagents reacted on it much in the same manner as upon the globules of high speed steel. Thus in view of the evidence presented we believe we are justified in stating that the embedded globules in high speed steel are of a complex but similar chemical composition and should be designated as tungstides instead of carbides though they are not pure tungstides.

Tungstides Are of a Eutectic Composition—The structure of the ingot lends an interesting aspect to the constitution of high speed steel. Fig. 32 shows a micrograph of the ingot as cast taken at 200 diameters magnification. The part of the ingot indicated by *A* probably solidified, first giving rise to a eutectic mixture represented by *B*. But at the same time this eutectic is solidifying areas of the molten solution entrapped by the first solidification precipitates the same eutectic, *C*, since the solution by partly solidifying enriches the remainder in those elements that will produce the lowest melting mixture.

Upon annealing the ingot only two constituents are noticeable as shown by Fig. 33. Then by etching the specimen with H_2O_2 NaOH we get a structure represented by Fig. 34. The eutectic marked *B* corresponds to that marked *B* in Fig. 32 and the eutectic marked *C* likewise corresponds to that marked *C*. Thus from evidence presented elsewhere in this paper these two constituents are the same, differing only in quantity as one has been precipitated from a mixture richer in the eutectic than the other. Thus the embedded tungstides in high speed steel must represent a eutectic mixture and as the eutectic changes with a change in the composition of the steel, the carbides do not represent a composition of a constant chemical formula.

While studying the structure of the ingot it is interesting to note the structures developed in high speed steel by hardening from a temperature at which an actual fusion of the tungstide takes place. In Fig. 35 the structure is comparable to the structure of the ingot as cast where there exists a large skeleton of the eutectic and an area of the eutectic having a more granular appearance. By etching the specimen from which this micrograph was made with (NaOH) - (H_2O_2) we get a structure as is shown by Fig. 36. That the skeleton of the eutectic of tungstides here represented is a fusion of the tungstides is evidenced by

Figs. 37 and 38 taken along a bar, one end of which was held at room temperature while the other was melted. A coalescing of the tungstides is very pronounced.

The black areas represented in Fig. 39 we believe were one time named "the brittle constituent" by a well-known English metallurgist and have been at other times called troostite, and only recently a similar micrograph was used by a well-known authority to represent correctly hardened high speed steel. These black areas however are the same as those shown in Fig. 35, and represent a fusion. In proof of this and also in proof that the areas are not troostite, the specimen from which this micrograph was made was annealed and Fig. 40 represents the result. Notice that the small faint areas of the tungstide are the same as the black areas in Fig. 39, and compare with the granular areas shown in Fig. 35 showing that a eutectic has resulted from an incipient fusion.

Influence of Chromium on Solution of Tungstides—From analyses of tungstide residues of high speed steel as given by Professor Arnold[11], to one of which reference was previously made, it was noted that the proportionally larger percentage of the chromium existing in high speed steel was to be found in the matrix. This is supported by Figs. 41 and 42 of steel containing 0.30 per cent carbon and 11.93 per cent chromium, and 0.31 per cent carbon and 15.90 per cent chromium, in which no carbides of chromium can be distinguished, and which have the appearance of a perfect solution of the chromium in the iron. Likewise from the analysis of the tungstide residues it is apparent that a proportionally larger percentage of the tungsten is contained in the tungstides, and in a tungsten steel of some 0.70 per cent carbon there exists a large number of embedded globules as would be expected but not near the proportion of these globules will go into solution at high temperatures as the tungstides in high speed steel indicating that iron dissolving chromium has a greater power to dissolve the tungstides than iron alone.

The Distribution of the Tungstides—The distribution of tungstides in high speed steel is of great importance as a poor distribution gives rise usually to a noticeably inferior steel. The following two micrographs, Figs. 43 and 44, are taken from the same ingot, one taken ⅛-inch from the outside and the other 2½ inches from the outside. The magnification of both are the same.

The distribution of the eutectic mixture or of the tungstides is evident as it existed in this ingot. The finer cellular structure is of course the result of the quicker freezing of the outside of the ingot, and as the ingot solidified progressively toward the center, the cellular structure grows coarser in about the same ratio as the rate of solidification of the ingot. Therefore, the correctly cast smaller ingot by solidifying more rapidly than the larger ingot has a more uniform and finer cellular structure. Moreover, obviously the ingot cast at a lower temperature will have a better cellular structure than an ingot cast at a higher temperature. Thus the size of the ingot and the casting temperature by determining the distribution of the eutectic mixture or tungstides determine partly the distribution of the tungstides in the finished product. Figs. 45 and 46 show two micrographs, taken longitudinal of two ¾-inch square bars rolled from different portions of the ingot. Fig. 45 was rolled from a 1½-inch square cut from the outside of a 7-inch ingot, while Fig. 46 was rolled from a 1½-inch square cut from the center of the same ingot.

Both bars received the same kind and amount of work yet the

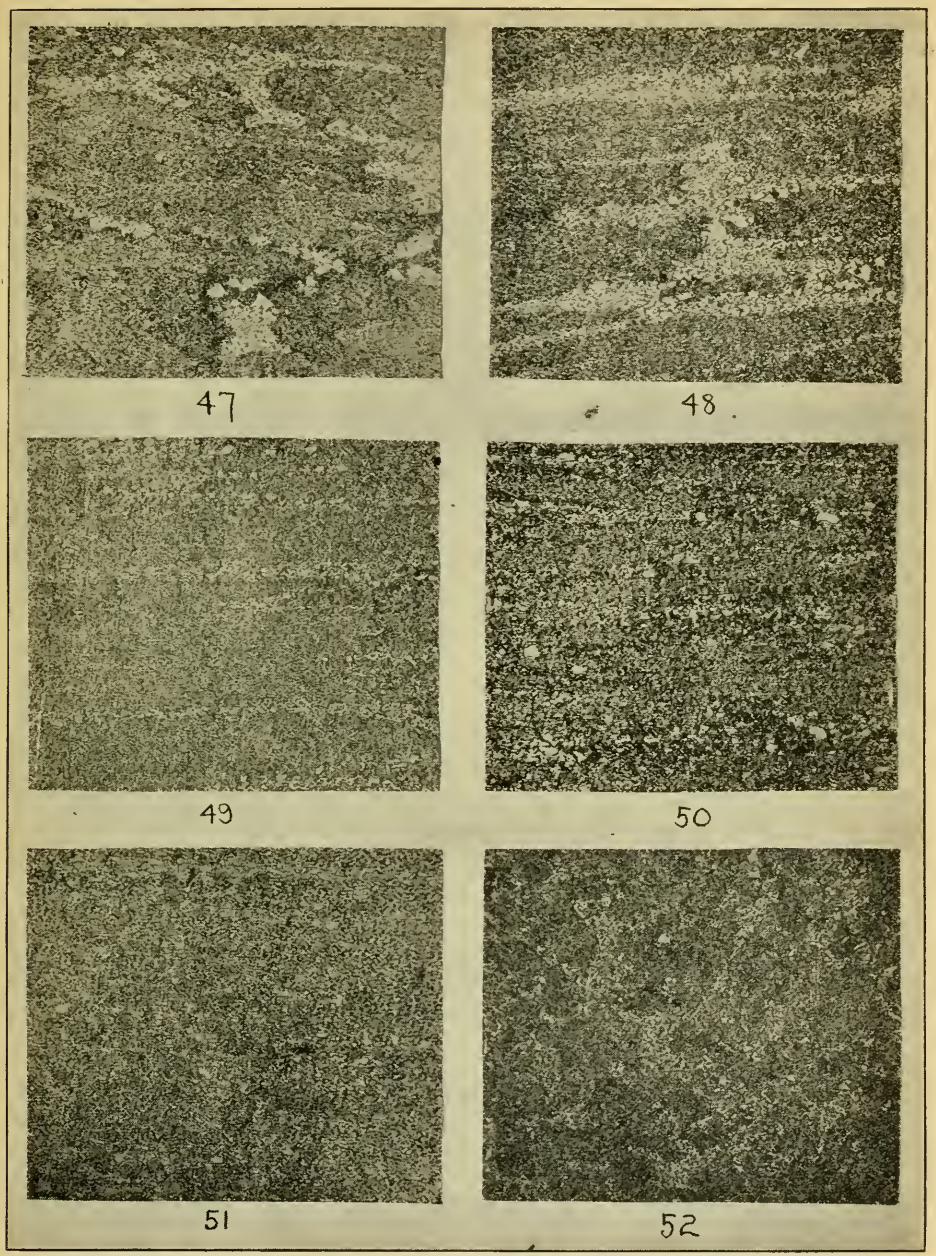
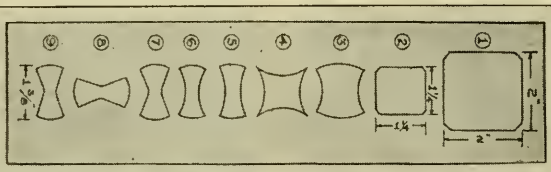


Fig. 47-52—Micrographs of longitudinal sections of ingot after various amounts of work. All etched with nitric acid and X275. Fig. 47—A 5½-inch billet rolled from 7-inch ingot. Fig. 48—A 3½-inch round rolled from 4-inch billet from 7-inch ingot. Fig. 49—A 2¾-inch round from 4-inch billet from 6-inch ingot. Fig. 50—A 1½ inch round from 2½-inch billet from 4-inch billet from 6-inch ingot. Fig. 51—A ¾-inch round from 2½-inch billet from 4¼-inch billet from 6-inch ingot. Fig. 52—Distribution of tungstides obtained in a block 9¼ x 6 x 1½ inches by upsetting

tungstide distribution in the bar cut from the outside of the ingot where the cellular structure was finer is far superior to that cut from the inside of the ingot where the cellular was so much coarser. This distribution is further determined by the amount and manner of reduction given the ingot and billet, and a number of micrographs taken of the longitudinal section show clearly the result of the amount of work given an ingot. Fig. 47 is a 5½-inch billet rolled from a 7-inch ingot. Fig. 48 is a 3⅛-



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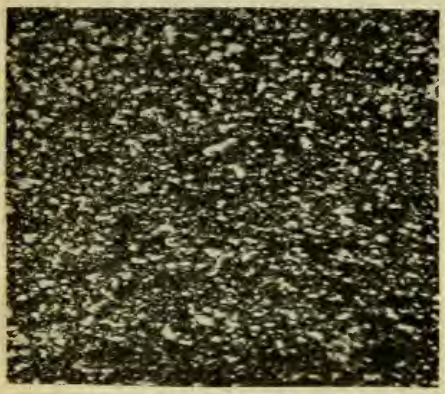

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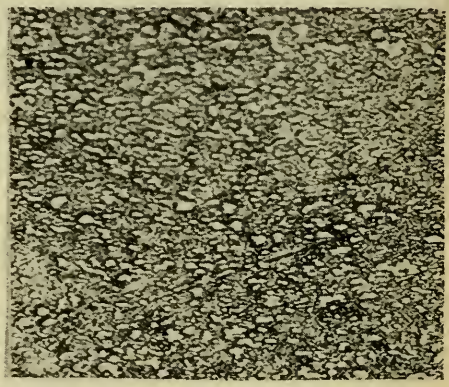

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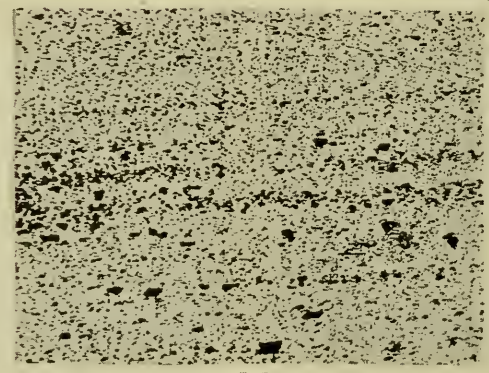

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Fig. 53—Diagram showing how good distribution may be obtained by working steel in same direction but in and out during passes through mill. Figs. 54-55—Longitudinal micrographs of 1⅜-inch drill section rolled according to diagram in Fig. 53. Etched with nitric acid and X500. Fig. 56—Micrograph of 1⅜-inch round rolled in the ordinary manner. Etched with sodium hydroxide—hydrogen peroxide and X275

inch round rolled from a 4-inch billet from a 7-inch ingot. Fig. 49 is a 2¾-inch round from a 4-inch billet from a 6-inch ingot. Fig. 50 is a 1½-inch round from a 2½-inch billet, from a 4-inch billet, from a 6-inch ingot. Fig. 51 is a ¾-inch round from 2½-inch billet, from a 4¼-inch billet from a 6-inch ingot.

In Fig. 51 a perfect distribution has been obtained by working the steel in the same direction, but as this came from a 6-inch ingot the reduction has been very great. If then a good distribution of the tungstides cannot be obtained by ordinary reduction, the manner of reduction must be changed, and Fig. 52 shows a splendid distribution of the tungstides obtained in a block 9¼ x 6 x 1½ inches by upsetting. The micrograph is taken in the direction of the longitudinal section of the bar from which the block was cut and upset.

A good distribution may be obtained by working the steel in the same direction but in and out as illustrated by the diagram shown in Fig. 53 of rolling drill section, where several passes through the rolls are made keeping the bar in a shape similar to that represented by the cross-section No. 4. Figs. 54 and 55 show longitudinal micrographs of a 1⅜-inch drill section rolled according to the diagram.

Fig. 56 shows a micrograph of a 1⅜-inch round rolled in the ordinary manner. From these micrographs the superiority of the manner of rolling the drill section is evident.

Summary—1. The position of the decalescence points in high speed steel are exceedingly constant while the position of the recalescence points depend on the temperature from which cooling begins. The upper decalescence point represents the solution of the tungstides while the lower recalescence point represents their formation. The lower decalescence point and the upper recalescence point represent respectively the transformation of sorbite into austenite, and austenite into a lower constituent.

2. Secondary hardness represents a natural occurrence and is dependent upon the carbon-chromium-tungsten content as well as the temperature from which cooling begins and the rate of cooling.

3. An alcoholic solution saturated with picric acid was found best for the etching of annealed specimens, while an alcoholic solution containing from 6 to 8 per cent HNO_3 was best for hardened specimens. A solution of sodium hydroxide and hydrogen peroxide, and a solution of $K_3Fe(CN)_6$ were found valuable for developing the tungstides. Heat tinting could also be used.

4. The nomenclature of the constituents of carbon steels is applicable to the constituents of high speed steels.

5. The embedded globules in high speed steel are of a complex but similar chemical composition, and should be designated as tungstides.

6. The tungstides are of a eutectic composition.

7. Iron-dissolving chromium has a greater power to dissolve the tungstides than iron alone.

8. The distribution of the tungstides depends upon the size of the ingot and the casting temperature as well as the amount and manner of reduction given the steel from the ingot to the finished bar.

SELECTION OF STEELS FOR AUTOMOBILES

By W. E. Jominy

ONE of the fundamentals of successful automobile construction lies in the proper selection of materials. However good the design may be otherwise, failure often results through the improper selection of materials by the designer. In this paper, the selection of steels for automobiles will be considered. Questions of fabrication and design will be considered only as they affect this. The subject has been divided into two main parts. The first part is a consideration of the various factors governing the proper selection of a steel for a given part. The second part is a discussion of the steels most commonly used in present day practice, giving the relative merits of each.

The kind of steel used in any automobile part depends largely upon its design. Lightness, distribution of metal, rigidity, ample radii at corners, tendency toward warping, all of which are embraced in the design of a part, largely control the steel which shall be chosen for the part. For example, most manufacturers use a high grade alloy steel for the rear axle shafts, yet there is a prominent maker of a medium grade automobile who uses ordinary open-hearth plain carbon steel for this part. Again there is a well known low priced car, which has heat treated alloy steel connecting rods, while most manufacturers use heat treated plain carbon steel, and one high grade manufacturer uses annealed plain carbon steel for his connecting rods. Obviously there is a great difference in the physical properties developed in these steels, but in any of the cases just mentioned, it is unlikely that the wrong material has been chosen. The differences in materials are largely the result of the different designs. There are a great many other considerations besides design in selecting the proper steel for a given part, but it is necessary first to know approximately what physical properties are required before any intelligent selection can be made. There are relatively few automobile parts in which the stresses can be figured accurately, but in many cases an approximate figure can be obtained. The required ductility for any part cannot be figured in any way, and for this reason there is much conjecture about this property, which is equally as important as the elastic limit of the steel.

Many engineers pay little attention to the ductility required in any given part, and investigate only the elastic limit required. It should be emphasized that the ductility of a steel is equally as important a property as its elastic limit and that failures occur just as quickly, in fact usually more quickly, when the ductility is too low than when the elastic limit is too low. The minimum ductility required for any part must be determined by the cut and try method, since there is no way of calculating it. Fortunately for parts of like function the minimum ductility required is about the same, so that once determined it can be applied generally. For example, the leaves in a chassis spring should have an elongation of about 9 per cent or better and a reduction of area of about 28 per cent or more to function satisfactorily; and whether the spring is lightly stressed or heavily stressed, or whether

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A paper presented by title at the Indianapolis Convention. The author, W. E. Jominy, is metallurgist, Studebaker Corp., Detroit.

it is used on a light touring car or heavy truck, the same minimum elongation is required.

To choose the proper steel for a given part then, we will first decide what minimum elongation and reduction of area it will be necessary to maintain, and then select those steels which, when heat treated to give an elongation over the minimum required, will give the desired elastic limit. Usually there will be half a dozen or more steels which will answer our purpose. If the part is subjected to large alternating stresses it may be expedient to further limit the possible number of steels for a given part by choosing those having high Stanton values and high impact values. Even limited in this way there will probably be several steels usable for any part from which must be chosen the most economical one to use.

In many cases properties other than structural are required, such as resistance to wear, resistance to burning, high tensile properties when hot, magnetic permeability, resistance to corrosion, etc. The same method of choosing steels for these parts can be used as mentioned above; the additional properties required simply limit the number of steels from which we must choose the most economical.

The most economical steel is not necessarily the one with the lowest first cost, although this is a consideration along with the ease with which the steel can be forged, burned, annealed, heat treated, warped, straightened and machined. Ability of the mill to consistently produce the steel free from pipes, seams and the many inherent defects, as well as possible sources of supply all enter into the problem. These qualities are not easily ascertained and require careful study of their use on a production scale. Experiments carried out on a production scale introduce so many variables that it is difficult to arrive at accurate results. The large difference in shop methods, as well as the differences in the number of cars produced per day, are perhaps the main reason why all shops are not unanimous in the choice of one type of steel.

Chrome-nickel, straight nickel, chrome-vanadium and recently chrome-molybdenum steels each have their staunch supporters, and undoubtedly each excels the others under certain conditions. For any given shop there is generally one steel which proves most economical, and the tendency is to use this wherever possible. This tendency should not be criticized, because it is desirable to use as few steels as possible in a plant. A reduction in the number of steels used means a reduction in the heavy investment an automobile manufacturer has in his stock of steel. It also makes for better purchasing conditions, better production conditions and less chance for mixing steels. Summing up the manufacturer's metallurgical problem, we find that he wishes as few different steels as possible which will meet his shop conditions economically and possess physical properties to satisfy the requirements of his many parts.

Having these requirements in mind, the following list of steels has been drafted and is intended to cover the needs of a manufacturer who is making all his parts at his own plant. Only the relatively important parts are mentioned, but these steels should take care of all parts.

(1)—A steel for sheets and strips of average importance. This is usually an open-hearth 0.10 per cent carbon steel, the same as S. A. E. No. 1010. It is used for fenders, body plates, splashers, hoods and various stampings. It is finished in most any degree of smoothness desired

and annealed in various ways to produce ordinary or extra deep drawing qualities.

(2)—A good machining steel for ordinary bolts, nuts, screws, studs and many other parts which are lightly stressed. A cold rolled or drawn bessemer steel of carbon content about 0.08 to 0.16 per cent, corresponding to S. A. E. No. 1112, is generally used. More attention is paid to the machinability of this steel than its strength. It is not considered a good carburizing steel, although it is used for this purpose by some makers of low priced cars. Because of its easy machining qualities it is popular with men in charge of production work.

(3)—A plain carbon carburizing steel for such parts as camshafts, tappets, spring bolts, water pump shafts, front end gears, etc. Following is the most common steel used for these parts:

	Per cent
Carbon	0.15—0.25
Manganese	0.30—0.60
Sulphur	0.050 maximum
Phosphorus	0.045 maximum

This steel is easily forged and machined although its machining qualities are not as good as steel (2) given above. After carburizing it is necessary to water quench this steel to produce a scleroscope hardness of 75 or more. If the steel is properly heat treated the Brinell hardness of the core will not exceed 200. It is not customary to refine the grain of the core of camshafts, tappets or water pump shafts. In the case of tappets and water pump shafts it is not deemed necessary and in the case of camshafts too much warpage is induced. Some makers use a steel ranging in carbon from 0.10 to 0.20 per cent for these parts. Better ductility results from the use of this steel but it is more difficult to machine.

(3-*a*)—Stampings, parts made from seamless tubing and frames are made from the same analysis steel given under (3). Frames also are quite commonly made from a 0.20 to 0.30 per cent carbon steel, other elements the same as under (3).

(4)—A forging steel of medium carbon for parts not too highly stressed, commonly used for connecting rods, crankshafts, front axles, spring clips, brake levers, etc. Many manufacturers use alloy steels for some of these parts and, as previously stated, the design largely determines which steel must be used. The medium carbon steel, however, is the most economical steel for these parts and if the design permits this steel will be used. If the design requires steels of higher physical properties some of the alloy steels which will be discussed later can be used. Following are the steels generally used in this group:

	(a) Per cent	(b) Per cent
Carbon	0.30—0.40	0.35—0.45
Manganese	0.50—0.80	0.50—0.80
Sulphur	0.050 maximum	0.050 maximum
Phosphorus	0.045 maximum	0.045 maximum

Both of these steels forge easily, respond well to heat treatment and are fairly easy to machine. Unless the sections are very irregular water may be used as the quenching medium. The Brinell hardness to which these parts are usually held depends again upon their design, but it will be found usually that when made from this steel connecting rods will

have a hardness somewhere between 190 and 290, crankshafts between 217 and 290 and front axles between 190 and 260.

(5)—A spring steel for coiled springs, lock washers, etc. This steel will have the following analysis:

	Per cent
Carbon	0.58—0.70
Manganese	0.70—1.00
Sulphur	under 0.050
Phosphorus	under 0.045

Where the size is suitable, coiled springs generally are coiled from wire of this analysis which has been tempered at the mill. After coiling, the springs are given a low draw at about 500 degrees Fahr. to remove the coiling strains and used in this condition. Whether tempered at the mill or heat treated at the spring plant, satisfactorily coiled springs will have a scleroscope hardness between 55 and 70.

(6)—A steel for keys, coiled springs of thick wire and ball bearing balls. Following is the steel generally used here:

	Per cent
Carbon	0 90—1.05
Manganese	0.25—0.50
Sulphur	under 0.045
Phosphorus	under 0.040

This steel is also used in low priced cars for chassis springs.

(7)—An alloy carburizing steel for parts where resistance to high stresses as well as wear is a factor, as case hardened gears, piston pins, steering knuckle pins, differential crosses, ring gears, ball bearing races, etc. Here we find a diversity of opinion as to the steel required. The following steels are most common:

	(a) Per cent	(b) Per cent	(c) Per cent	(d) Per cent	(e) Per cent	(f) Per cent
Carbon	0.10—0.20	0.15—0.25	0.15—0.25	0.15—0.25	0.15—0.23	0.08—0.16
Manganese	0.50—0.80	0.50—0.80	0.50—0.80	0.50—0.80	0.30—0.60	0.30—0.60
Sulphur	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.
Phosphorus	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Chromium	.....	0.45—0.75	0.80—1.00	.....	1.00—1.20	1.00—1.20
Nickel	3.25—3.75	1.00—1.50	.....	3.25—3.75	3.00—3.50	3.00—3.50
Vanadium	.....	.....	0.15—0.20	.....	.....	.....

Steel (*a*) is easy to heat treat and gives highly satisfactory results, producing a very ductile core. Unless carefully prepared, however, it is rather difficult to machine.

Steel (*b*) machines a little easier than (*a*), but does not give quite as ductile a core.

Steel (*c*) is a good carburizing steel, but due to the increasing cost of vanadium, the steel has a rather high first cost.

Steel (*d*) is easier to machine than (*a*) but does not give quite as ductile a core and requires a little more care in heat treatment.

Steel (*e*) requires careful heat treatment to produce a soft core and a hard case, and several concerns have not been able to use it successfully on a production scale. When properly heat treated, however, this steel has good physical properties, and has been the salvation of some otherwise impossible designs.

Steel (*f*) gives excellent physical properties and is much easier to heat treat than steel (*e*). Where heat treating difficulties are encountered,

steel (*f*) is often substituted to advantage for (*e*). Steel (*f*), however, is more expensive than (*e*).

All of these steels can be hardened to a scleroscope hardness of 75 minimum, using oil as a quenching medium, in fact, many manufacturers require a minimum of 80. Water can be used as a quenching medium for steels (*a*); (*b*), (*c*) and (*d*) for some sections, but because minimum warping is desired oil is generally used. Nearly all parts made from those steels are double quenched. An exception to this is the ring gear, which is seldom double quenched because the high heat to refine the core produces too much warping.

(8)—A steel for the usually high stressed parts such as rear axle shafts, steering knuckles, propeller tubes, steering arms, connecting rod bolts, highly stressed studs, etc. Where design makes it necessary, front axles, spring clips and connecting rods are also made from this steel. Here there is a wide range of steels used:

	(a) Per cent	(b) Per cent	(c) Per cent	(d) Per cent
Carbon	0.25—0.35	0.25—0.35	0.25—0.35	0.30—0.40
Carbon	0.30—0.40	.....	0.30—0.40	.....
Carbon	0.35—0.45	.....	.....	.....
Manganese	0.50—0.80	0.50—0.80	0.50—0.80	0.30—0.60
Sulphur	0.045 max.	0.045 max.	0.045 max.	0.045 max.
Phosphorus	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Chromium	0.45—0.75	0.80—1.10	.....	0.60—0.95
Nickel	1.00—1.50	.....	3.25—3.75	2.75—3.25
Vanadium	.....	0.15 min.	.....	.....

Where different carbon ranges are given it should be remembered that the lower the carbon content the easier the steel is to forge, anneal, machine and heat treat but also the lower the carbon the lower the physical properties of the steel.

Steel (*a*) is a popular steel. It forges rather easily, is not difficult to anneal, responds well to ordinary heat treatment, although in general requires oil quenching, and gives good physical properties.

Steel (*b*) forges easily, is easy to anneal, is easily heat treated and far less sensitive of over heating than (*a*), (*c*) or (*d*). It can be quenched in water and gives good physical properties. Due to the high cost of vanadium, the first cost is rather high and because of higher heats required to treat it, is a little harder on the furnaces.

Steel (*c*) is rather easily forged, is not difficult to anneal or heat treat, but the hardness does not penetrate well in large sections. In small sections it gives satisfactory physical properties. This steel also seems to have more inherent defects than the others.

Steel (*d*) is rather difficult to forge, difficult to anneal, requires careful heat treatment but gives excellent physical properties. Usually when steel (d) is used in a manufacturer's plant it is because of some one particular part and he makes all his other parts in this group out of steel (*a*), (*b*) or (*c*).

Chrome-molybdenum steel has been introduced recently as an automobile steel with what seems to be a promising future. At the present time, however, it has not been sufficiently used in quantity production to include it in our list.

(9)—A steel for gears. This function requires all that we can get from a steel. We must have resistance to wear, to shock, and to very high stresses. There are still quite a number of cars made with carburized gears and in this case one of the steel under (No. 7) is used. The general con-

sensus of opinion seems to be, however, that all things considered, the oil hardened gear is more satisfactory. The following are the more common steels:

	(a) Per cent	(b) Per cent	(c) Per cent
Carbon	0.45—0.55	0.40—0.50	0.45—0.55
Carbon	0.40—0.50	.....	0.40—0.50
Manganese	0.30—0.60	0.50—0.80	0.50—0.80
Sulphur	0.040 max	0.045 max.	0.040 max.
Phosphorus	0.040 max.	0.040 max.	0.040 max.
Chromium	0.60—0.90	.....	0.45—0.75
Nickel	1.50—2.00	3.25—3.75	1.00—1.50

Steel (*a*) is difficult to forge, difficult to anneal, hard to machine, must be heat treated with great care but gives excellent results. The steel with the lower carbon range eases these difficulties.

Steel (*b*) is a little easier to forge and anneal than steel (*a*) but in large sections the hardness does not penetrate as well as in the other steels. It does not have physical properties as good as (*a*).

Steel (*c*) is somewhat easier to forge, anneal and machine than (*b*) and has about the same physical properties.

Gears made from these steels and heat treated to a scleroscope hardness of 70 to 75 seem to give the best results.

(10)—A steel for chassis springs. We have already discussed the plain carbon steel that is used for lightly stressed springs. There are three other steels which are commonly used which have the following analysis:

	(a) Per cent	(b) Per cent	(c) Per cent
Carbon	0.45—0.55	0.40—0.50	0.65—0.75
Manganese	0.60—0.80	0.80—1.00	0.85—1.05
Sulphur	0.045 max.	0.040 max.	0.035 max.
Phosphorus	0.045 max.	0.040 max.	0.035 max.
Silicon	1.80—2.10	.....	0.30 max.
Chromium	.....	1.05—1.20	0.30—0.45
Vanadium	.....	0.15 min.	.....

These steels all give good results. Steel (*c*) is generally conceded to be the best of these three, but it is more delicate and consequently more difficult to handle than the other two. The hardness of the spring leaves should be as close to 400 Brinnell as is commercially possible to maintain.

(11)—A magnet steel. The following analysis is common for this purpose:

	Per cent
Carbon	0.80—0.90
Manganese	0.30—0.50
Silicon	0.25—0.40
Chromium	1.90—2.10
Tungsten	0.75—1.00

(12)—A valve steel. Strength, resistance to wear and resistance to scaling at elevated temperatures characterizes a good valve steel. Most of the lower priced cars have valves made from a cast iron head cast or welded onto a machine steel stem. These valves resist scaling at high heats, quite satisfactorily but warp and pit easily. If better materials are required one of the following steels should prove satisfactory:

	(a) Per cent	(b) Per cent	(c) Per cent	(d) Per cent	(e) Per cent	(f) Per cent
Carbon....	0.25—0.35	0.50—0.70	0.50—0.70	0.20—0.40 or 0.40—0.50	0.40—0.50	1.20—1.50
Manganese	0.50—0.80	0.30 max.	0.30 max.	0.050 max.	0.30 max.	0.20—0.30
Sulphur...	0.045 max.	0.035 max.	0.035 max.	0.035 max.	0.030 max.	0.035 max.
Phosphorus	0.040	0.035 max.	0.035 max.	0.035 max.	0.030 max.	0.035 max.
Silicon.....	.....	.....	.....	.....	3.50—4.50	0.40—0.60
Chromium.	.....	0.50—1.00	3.00—4.00	11.50—14.00	8.00—10.00	11.50–13.00
Nickel.....	3.25—3.75	.....	.....	3.00 max.	.....	0.40—0.60
Tungsten..	.....	1.50—2.00	13.00–15.00	.....	.....	.....
Cobalt....	.....	.....	.....	.....	.....	3.00—3.50

The principle merit of steel (*a*) is in its relative cheapness. It is easier to forge and machine than the other steels in this group and has the lowest first cost. It does not resist scaling well but will not warp as easily as the cast iron head valve.

Steel (*b*) costs a little more than steel (*a*) but is a little stronger at high temperatures and so resists warping better.

Steel (*c*) is the strongest steel of the group at high temperatures, 1200 to 1700 degrees Fahr. and for this reason has the highest resistance to warping.

Steel (*d*) is not as strong at high heats as (*c*) but resists scaling much better. For this reason (*d*) under most conditions is better than (*c*).

Steel (*e*) resists scaling a little better than (*d*) but is otherwise about the same.

Steel (*f*) resists scaling as well as (*d*) and is nearly as strong as (*c*) at high temperatures. It is about the best valve steel we have today which has been used on a production scale.

These 12 steels cover every need of the automobile engineer in designing a motor car. It has been necessary to be extremely brief in discussing each of these steels in order to cover them all. If a manufacturer makes every part of his automobile at his own plant, he will require a minimum of 12 steels, and if he uses cast iron head valves, he can cut down to 11. Under present conditions, this is the minimum number of steels from which an automobile can be built on a production scale. No manufacturer makes all parts for his automobile at his own plant, yet it is not at all uncommon to find 20 or more different steels in his stock. While it may not be possible for him to get down to a minimum of 12 steels, he should be able to get along with much less than 20. In these times of retrenchment and economy, it might be well for the manufacturer to consider the opportunity of large saving by reducing the number of steels in his stock.

HIGH PRESSURE GAS AND ITS APPLICATION TO INDUSTRIAL FURNACES

By F. J. Evans

EQUIPMENT that harnesses and regulates heat efficiently is comparatively new. Less attention has been given to "heat process management" than to the mechanical processes. Today, the cost of fuel and product requirements make heat engineering a vital phase of management.

The past few years have found the steel industry in the slow process of readjustment from conditions imposed by the war. Many furnaces used for war work have passed out of existence although in a few cases, certain of them have been adapted to other purposes. Beyond doubt, many manufacturers have had their attention drawn in such forceful ways to furnace design and furnace efficiency, and to methods for heating furnaces that the lessons learned will be of permanent value.

The attitude of manufacturers toward unfamiliar methods is not, as a rule, to their credit. They seem regrettably unwilling to follow the recommendations of their own engineers, also to hold the latter so rigidly responsible that nothing short of absolute certainty of success will induce the engineer, often an expert in his line, to make a recommendation. The lack of fuel experts, upon the engineering staffs of many large concerns is often noticeable.

In the treatment of steel it is important to heat the steel uniformly, and at a definite rate according to the particular operation. The work must be placed in the furnace so that all parts may become thoroughly and evenly heated for variation in the furnace temperature or uneven heating will invariably produce nonuniform results. Thus it is at once apparent that the temperature and atmospheric conditions of the heating zone of the furnace are of utmost importance. There are several factors which tend to influence this condition, the most essential of which are the kind of fuel used and the methods of its application. Since practically all fuels require a certain amount of free oxygen to support combustion, it is obvious that the best results will be obtained, all things being equal, with the fuel that will admit of an automatic means of proportionally mixing the oxygen with the fuel.

Coal, coke and oil by reason of their physical properties are not well suited for mixing automatically with air in the proper portions for complete combustion. Since all fuels except carbon must reach a gaseous state before combustion really takes place it is obvious that commercial gas of the proper composition and heating value would be the logical fuel to use.

In the combustion of any fuel it has long been the object of fuel engineers to effect complete combustion with a minimum amount of excess air, which obviously wastes a certain percentage of the heat. Any air beyond that amount required to completely burn a given quantity of fuel is not only unnecessary but is harmful in two ways; it carries off an amount of heat, depending upon the temperature of the flue gases, and it lowers the temperature below the maximum temperature obtainable when the fuel is burned with no excess air.

It has been only within the past several years that the properties of perfectly proportioned mixtures of air and gas have been well understood and the development of any practical process or apparatus capable of operating

A paper presented by title at the Indianapolis Convention. The author, F. J. Evans, is sales engineer, Surface Combustion Co., New York.

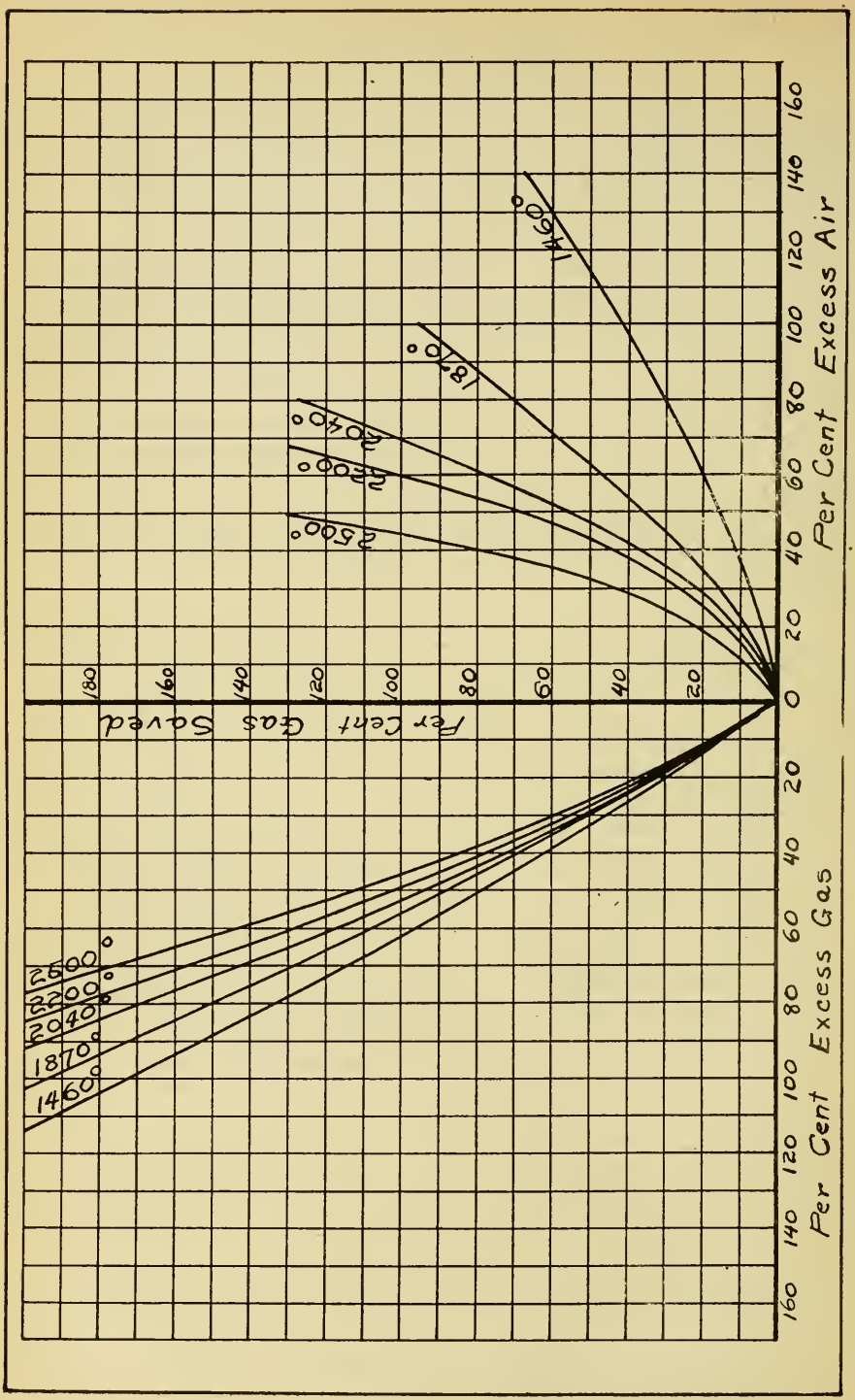


Fig. 1—Gas saved by correct proportioning in percentage of gas consumed with correct proportioning

on such mixtures has been accomplished. Further, the operator of any appliance usually has neither the inclination nor the ability to make manually the proper adjustments to secure the best mixture. It is therefore, quite usual for furnaces, under shop conditions, to run with 30 or 40 per cent excess air and many show a far greater percentage. Not infrequently the excess air content in the flue gases is accompanied by carbon monoxide which shows incomplete combustion. This condition results from stratification in the mixture stream and can only be corrected by obtaining a homogeneous mixture, that is, to have every particle of combustible in intimate contact with its combining proportion of oxygen. When this stratification occurs the generation efficiency is still further lowered, depending of course, on the percentage of oxygen and carbon monoxide found in the waste gases.

As a result of years of experience and experimenting to obtain the most economical and practical application of efficient combustion to the various heating operations which are encountered in the present industries, equipment has been produced which is essentially a mechanical application of engineering principles of combustion based upon discoveries developed through years of scientific research by some of the most eminent fuel engineers in this and other countries.

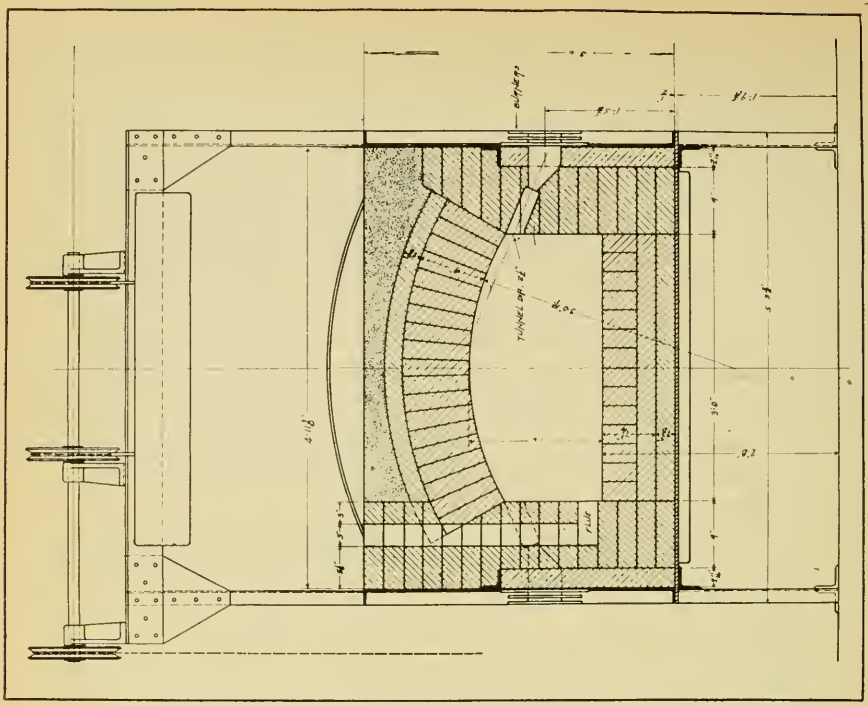
The term surface combustion in so far as it relates to heating problems merely refers to the well-known influence of light wave energy upon a gaseous mixture to accelerate chemical reaction. In other words it is light catalysis upon gas reactions. Surface combustion, therefore, can and does take place in any gas reaction zone where there is enough light wave energy to increase the speed of reaction by ionization of molecules, breaking up of molecules or otherwise changing their condition to facilitate more rapid readjustment.

In the application of a gas fuel to industrial plants three distinct systems are in common use:

1. Low-pressure air and gas system with two valve control and manual proportioning
2. Low-pressure air and gas system with single valve control and automatic proportioning
3. High-pressure gas system with single valve control and automatic proportioning.

Under the first system the efficiency of the furnace is at the mercy of three variables, namely, air pressure, gas pressure and the skill of the furnace operator. It is obviously unreasonable to expect that even a commercial degree of accuracy can ever be obtained with these three variable conditions. With the best of conditions it is impossible to avoid fluctuations in pressure of the gas and air supplies which must result in an impaired furnace atmosphere that may become oxidizing and therefore detrimental to the steel being treated, causing scale formation or it may become excessively reducing with an accompanying waste of fuel.

The losses occurring on account of these three variables are best illustrated by the curves shown in Fig. 1, published in the 1921 proceedings of the American Gas Association, showing the amount of fuel wasted at the various temperatures in a furnace due to improper proportions of air and gas expressed in percentage of the amount of fuel consumed in the furnace at the given temperatures with correct proportions of air and gas. These curves were derived by actual tests run on a small oven-type furnace. The fuel consumption required to maintain the furnace at the various temperatures was



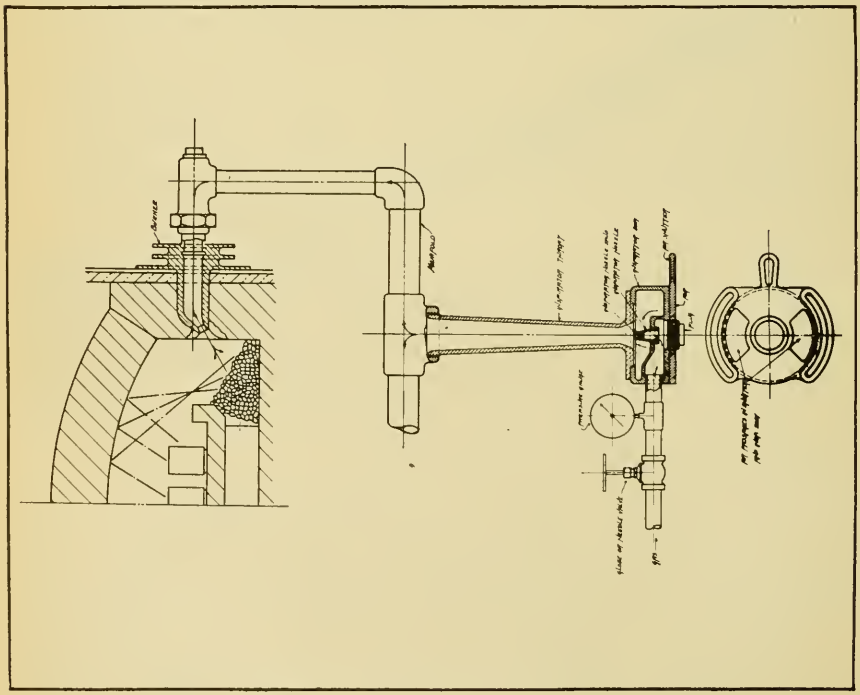


Fig. 2—(left) Diagram showing essential components comprising a high-pressure gas burner equipment. Fig. 3—(right) General design and construction of one type of furnace. See Fig. 5

first determined with a correct mixture and then with mixtures of various percentages of excess air and gas, and it will be noted that the losses greatly increase with the furnace temperature. For example: At 2500 degrees Fahr. and with 49 per cent excess air, the gas consumption was actually 360 cubic feet while with correct mixture the consumption was only 163 cubic feet. Therefore the gas saved by correct proportioning in percentage of the consumption with a correct proportioning would be $\frac{(360-163)\,100}{163}=121$ per cent as shown on the curve.

In both the first and second systems, the entire plant must be piped with large size pipes for both air and gas. An 8-inch pipe carrying gas under 10 pounds pressure would replace a 20-inch pipe distributing gas at the low pressures normally used. Low-pressure air cannot be piped efficiently for any great distance, thereby necessitating placing of individual blowers for each shop.

The third or high-pressure gas system eliminates all of the disadvantages. It is called the high-pressure system because the gas is delivered under pressure to the furnaces, the pressure required varying with the gas used. One and one-half ounces per square inch is satisfactory for blast-furnace gas, while 8 ounces to one pound will suffice for producer gas. Coke oven gas can be used at from 3 to 10 pounds, and natural gas at from 20 to 40 pounds pressure.

In many cases the gas to be used is available at the required pressure. When such is not the case a compressor is installed. The high-pressure gas entering the furnace equipment is projected through a nozzle into the throat of a venturi entraining tube. Flow energy, or inertia of the gas, causes the entrainment of the air necessary for combustion from the atmosphere. Proper selection of the gas nozzle will enable the production of a perfect mixture, or of one which is rich or lean, as may be desired. When the desired setting has once been made, the proportion of air and gas will remain true and constant throughout the range of the apparatus, which is usually about 4 to 1. The mixture becomes homogeneous at about the time it leaves the entraining tube to enter the manifold. This system does away with the necessity for air under pressure and the consequent air piping. The salient features of the high-pressure system are:

1. The absolute unvarying gas pressure in the pipe lines to the furnace, irrespective of the pressure conditions at the gas holder or the number of furnaces in use at any one time.
2. The maintenance of any constant homogeneous ratio of gas to air is supplied through the burners at all times and through all rates of furnace operation.
3. Highest quality of production—temperature and furnace atmosphere are controlled unvaryingly even by the most unskilled labor.
4. Daily reproduction of heating conditions with absolute certainty and without recourse to burner adjustment.
5. Highest possible combustion efficiency.
6. Highest possible output with minimum fuel consumption.
7. Gas compressor unit entirely automatic, reliable and economical.

The above are some of the more important advantages offered by the use of the high-pressure gas system, the realization of which is entirely de-

pendent upon the equipment used to deliver and maintain the proper and constant pressure of gas in the distribution lines to the furnaces and upon the proper application of equipment for heat generation.

The following points are of prime importance for satisfactory operation of any high-pressure gas burner equipment:

1. Operating characteristics of the equipment:

(a). Under this consideration it is necessary to appreciate that correct mixtures of air and gas are explosive and, therefore, require the greatest care in handling. The essential components which comprise a high-pressure gas burner equipment are the inspirator or automatic proportioning device, the burner through which the mixture is delivered into the fur-

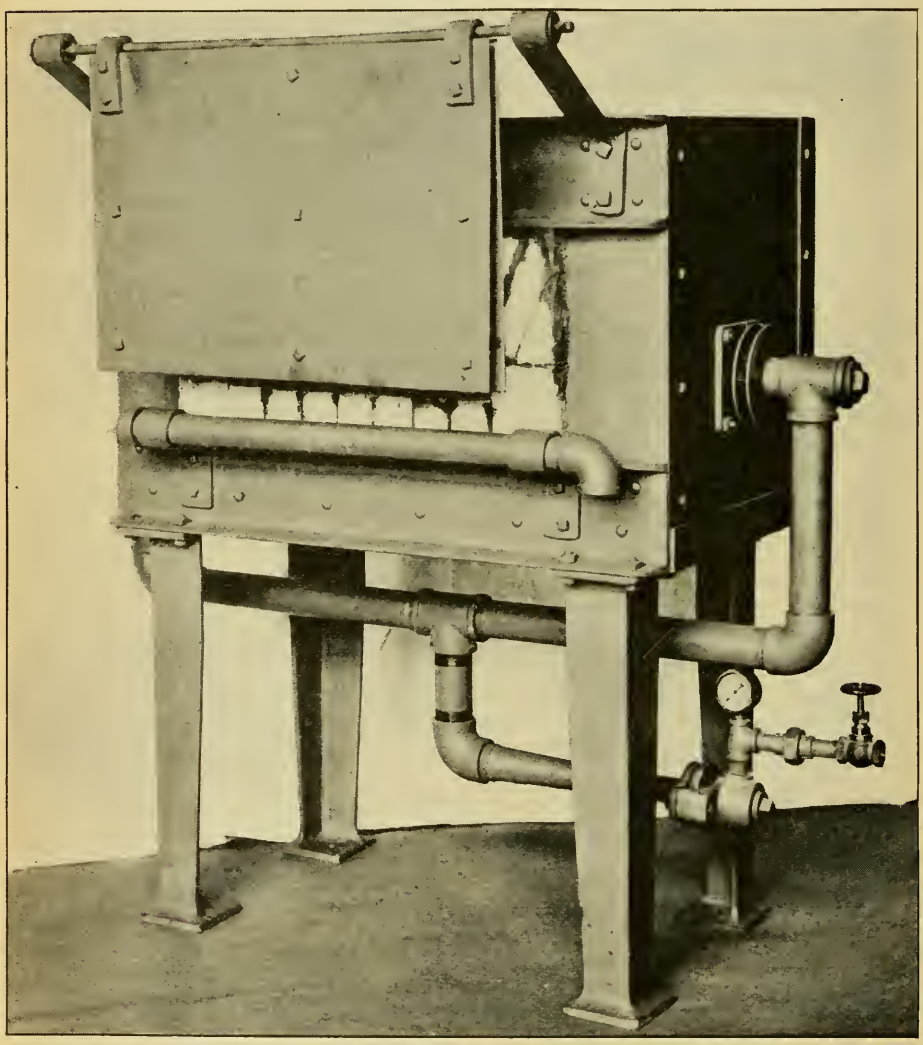


Fig. 4—A small standard furnace completely equipped

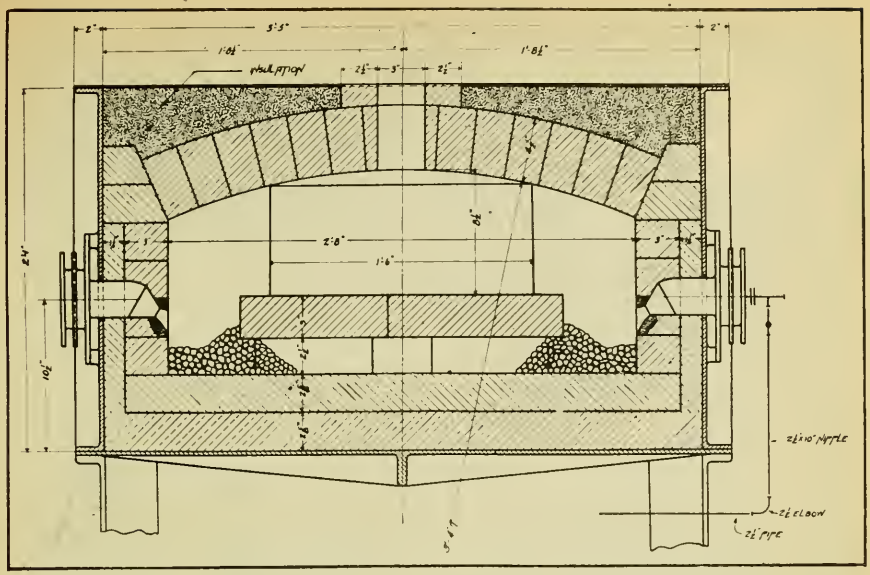


Fig. 5—General design and construction of another type of furnace. See Fig. 3

nace, the pressure gage and control valve and the manifold piping connecting all of these elements as shown by the drawing in Fig. 2. The photograph shown as Fig. 4 illustrates a small standard furnace completely equipped. Each inspirator must be designed and constructed so as to mix homogeneously the air and gas. Unless the entire equipment is aligned in certain proportions this will not be accomplished and incomplete combustion will result.

(b). The inspirator must have a high mechanical efficiency or in other words a wide range of regulation. One of the precautions against back-firing is in maintaining the pressure on the mixture at the burners well above that which permits the mixture as discharged at the burner to slow down to a velocity near the rate of flame propagation. There are numerous types of inspirators on the market which will draw in the proper proportion of air and maintain this pressure, but which do not give any range of regulation. In order to secure range of control the attempt is made often to install a large number of burners in a furnace, all of which burners operate at one fixed rate, and then to shut off such burners as may be found at certain rates of operation are not required. This necessarily calls for a complicated system of controls and will inevitably produce uneven heating when the furnace is being operated with some of the burners shut off as well as cause those burners which are not in operation to melt or burn off.

(c). The manifold piping, arrangement and size must be so designed as to prevent back-firing and to maintain the pressure head built up by the inspirator.

(d). Construction of the burner must be of a type which will

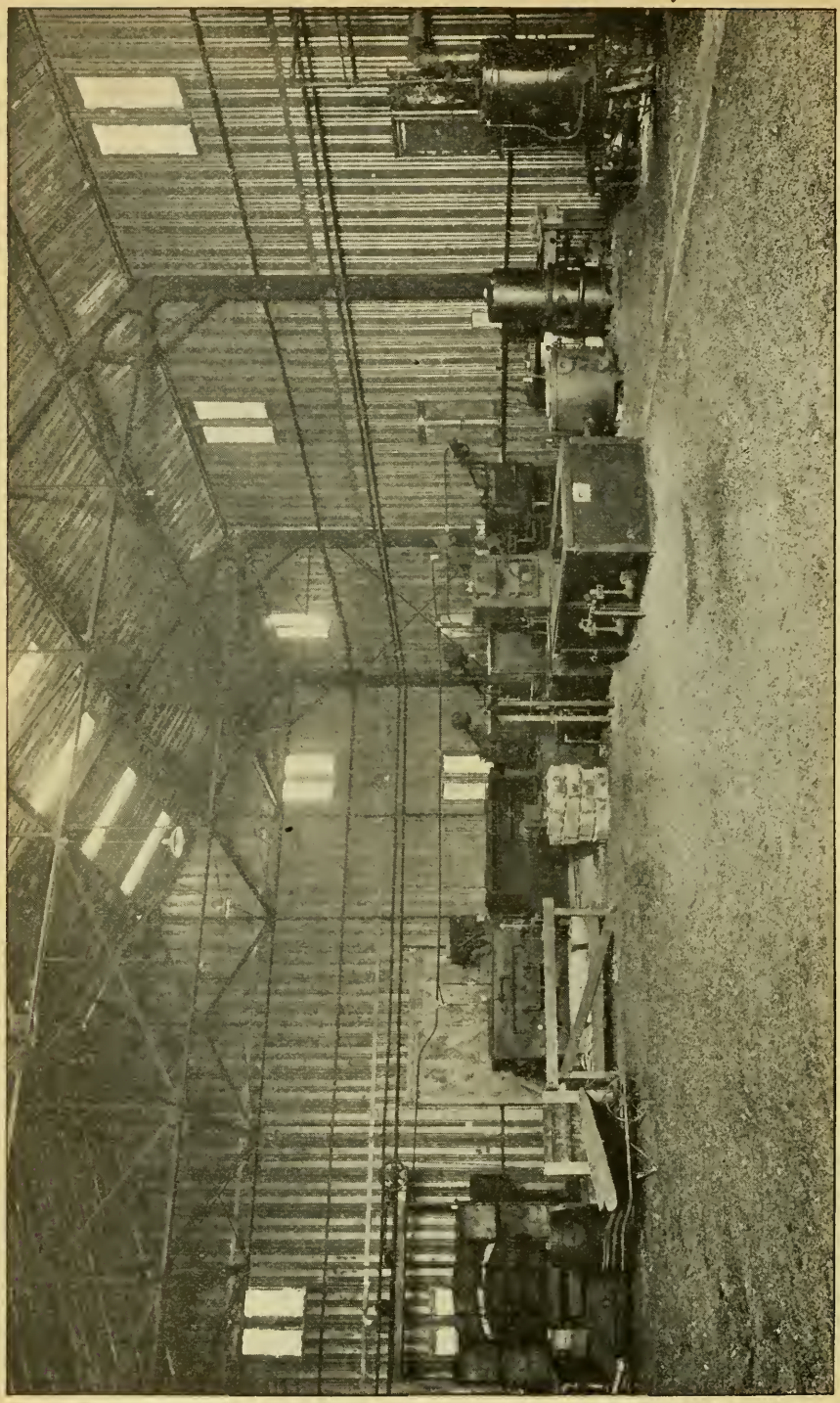


Fig. 6—Commercial heat treating plant completely equipped with high pressure gas system. Note absence of large and cumbersome piping

prevent over-heating and consequently destruction of the burner tip. This is not only an expensive item in cost of repairs but is also one cause of back-firing. Burners used with one well-known equipment are of a patented self-cooled type of a simple cast iron construction. Some of these burners have been in daily operation in steel welding furnaces for over three years without indications of burning out.

(e). On furnaces requiring equipment of such size that possible back-firing would be dangerous it is imperative that the

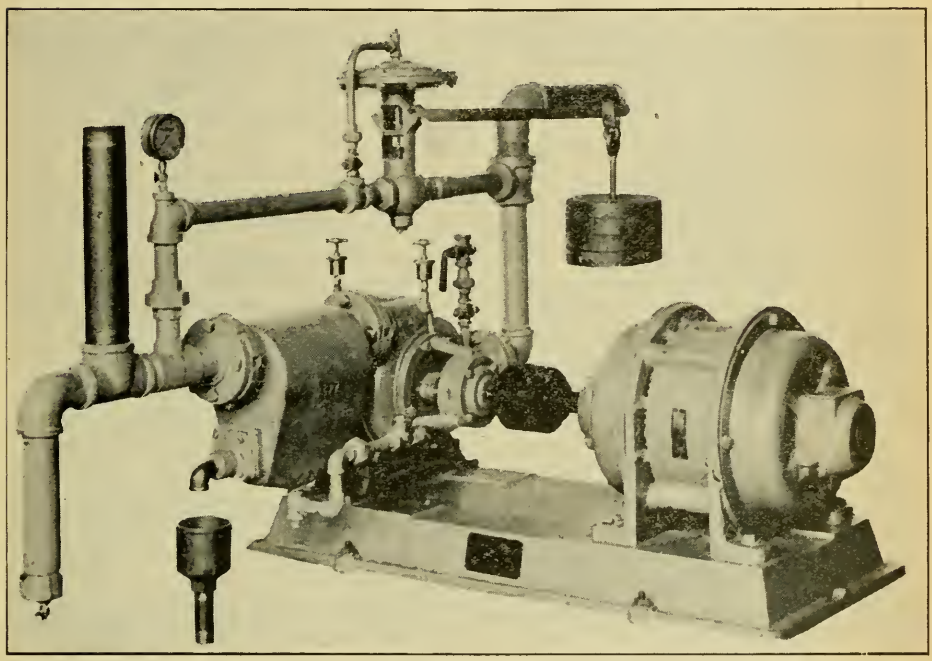


Fig. 7—A direct connected motor compressor unit equipped with by-pass and relief valve

equipment supplied should absolutely eliminate the possibility of back-firing.

2. Arrangement of the burners:

(a). Burners must be so arranged that equipment on each furnace is easily and simply controlled. Location of the burners depends upon the type of heating operation.

(b). Number and size of the burners depend upon the shape and size of the heating chamber as well as upon the amount and temperature of the work to be treated.

3. Size and shape of the combustion chamber in the furnace:

(a). In determining the size and shape of the combustion chamber of any furnace it is, of course, necessary to design this chamber in proportion to the amount of fuel to be consumed as determined by the amount of work to be treated. Dimensions of the heating chamber are also determined from

the same factors. Through experience gained from practice and research a definite and working ratio has been established for the cubic feet of gas consumed per hour to the square foot of internal heating surface for all types of furnaces.

4. Nature of the refractories:

(a). Certain sections of all furnaces fired by a homogeneous mixture of air and gas are subjected to much greater deteriorating effects than others regardless of the evenness of heating.

(b). The location of these heating zones is controlled by the proper design of equipment and these zones are then constructed of special refractories which easily withstand temperatures far in excess of those normally obtained. Fig. 3 and Fig. 5 illustrate the general design and construction of two types of furnaces as well as the location and construction of the heating zones.

5. Compressors:

(a). The compressors used for compressing the gas to the required pressure are of the rotary type which have no valves or reciprocating parts. The simplicity of construction and operation makes these units most reliable. The desired pressure is maintained automatically by means of a bypass equipped either with an automatic relief valve or with a patented unloader, and therefore can be operated by unskilled labor. The large units are equipped with the special unloader which employs the venturi principle to raise the pressure of the fresh gas supplied to the compressor by making use of the available pressure of the by-passed gas. These compressors can be direct connected on the smaller units, the large units being connected by a silent chain encased in an oil casing to the driving motor. Fig. 7 shows a direct-connected motor compressor unit equipped with by-pass and relief valve.

In the preparation of this paper the writer has endeavored to set forth the main points for consideration in the selection of a fuel system for an industrial plant. Heating cost is dependent upon the correct utilization of the fuel and is not wholly determined by the fuel cost. Therefore, the man who continues to draw his conclusions from results secured in the past by the use of obsolete or poorly designed equipment cannot choose wisely, and the many successful installations now in operation have proven that with modern methods and improvements gas used efficiently is an ideal industrial fuel capable of meeting keen competition with the other fuels or heating mediums.

THE FIELD OF RESEARCH IN INDUSTRY

By Edward P. Hyde

THE comprehensiveness of this paper reminds me a bit of the comprehensiveness of the name of a little hotel in Paris. The hotel was called, as a big sign across the front proclaimed, "Hotel de l' Univers et de Portugal," and I used to wonder why Portugal was considered "ex universa" and had to be added. Some time afterwards I observed at the bottom of the sign in small letters the explanatory word "reunis." In a somewhat similar way I should have several sentences in small letters explaining that it is not my intention in this paper to endeavor to cover the whole scope of possible research, and to fit every part of it into its appropriate nook and corner. The schematic chart, shown in the accompanying illustration, is introduced here simply to show what place research in industry takes in the general scheme, as the problem is analyzed.

You have heard much about the research idea. Dr. Howe has told you how it has progressed. No doubt Professor Adams and others emphasized last night and will emphasize again today what must already be very well recognized by all of you, that the spirit of research is rife. As a matter of fact, the pendulum is swinging so far that we wonder somtimes whether it has not gone beyond its equilibrium point. Sometimes I think that much that is done under the name of research is misnamed, and that much of it is really wasted effort. Not that any of us for a moment would question the value—the permanent, fundamental underlying value of real research work. It is necessary, however, to distinguish between genuine and spurious research—to encourage the one and prevent the other so far as possible.

The thought that I want to present to you of the field of research in in industry really comes out of what might be considered an academic picture of the research field. You may not agree with all of the distinctions which I have made in the chart. I am going to try to get you to believe the fundamental ones, or at least to present them to you in such a way that I can get some reaction that will change my own views. I want to start by distinguishing between scientific research and engineering. What is research, to begin with? Knowledge comes to us at times by chance, in a haphazard, fortuitous fashion, but only that is worthy of the name of research which comes as a result of diligent continuous seeking—of searching after facts and principles. The goal of research is truth. That, I think, is fundamental, whether the end in view is knowledge for knowledge's sake, or whether it is knowledge as a basis for application. Research is the way and means of getting at truth. It is scientific.

The distinction between scientific research and engineering is twofold in character. In the first place they are different because one consists in the acquisition of knowledge and the other in the application of knowledge; and in the second place they require a different training. Engineering is an art, and those who apply engineering are artists, or artisans, or any other term that you may use for those who are workers in an art. The training of an engineer is not the training of a research man, though there may be research men among engineers who are endowed peculiarly with the spirit of

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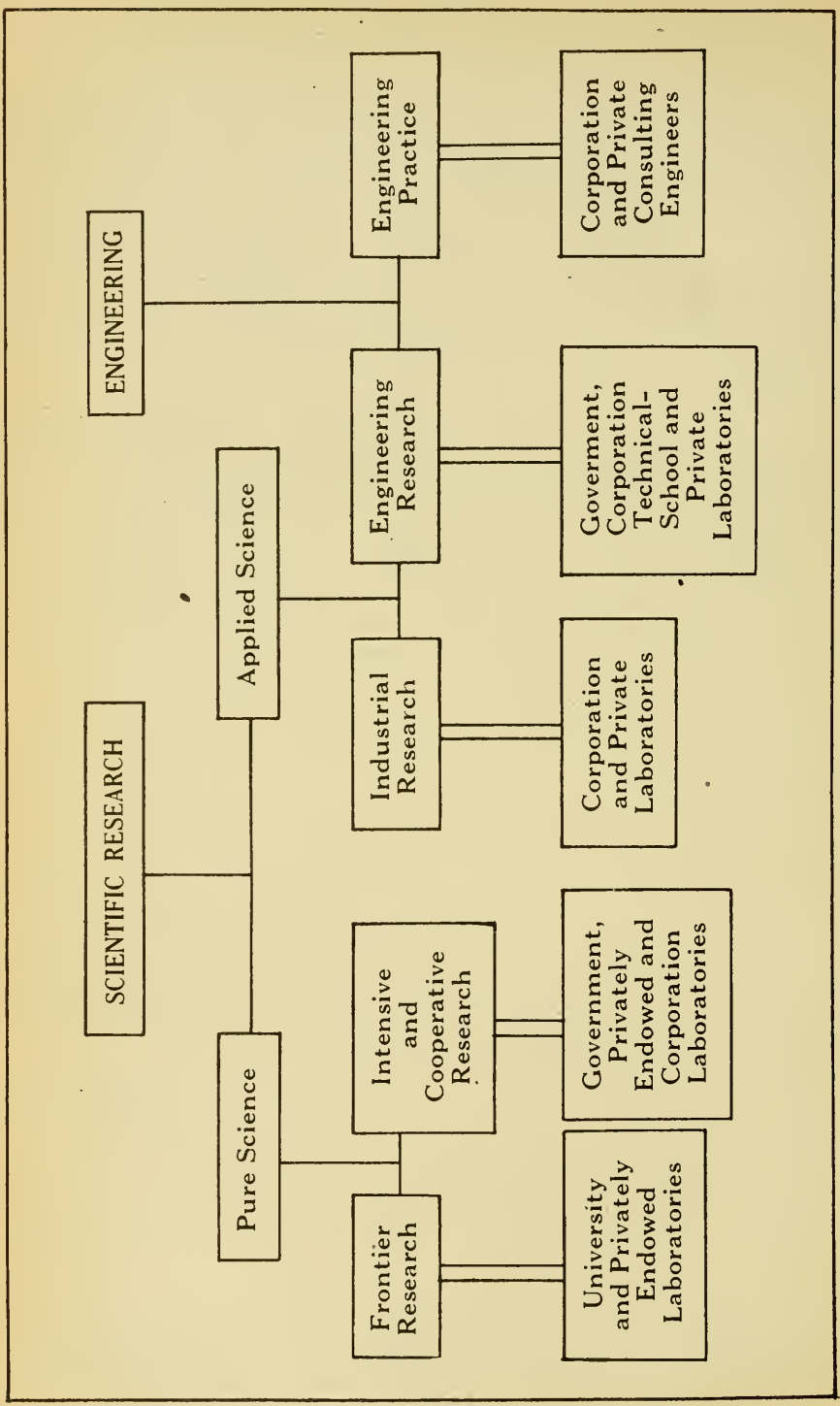
Revised stenographic notes of an informal paper presented before the research session of the Indianapolis Convention. The author, Dr. Edward P. Hyde, is director of research, Nela Research Laboratory, National Lamp Works of General Electric Co., Nela Park, Cleveland. The discussion of this paper will be found on page 98 of the November issue of TRANSACTIONS.



A CHART WHICH SHOWS THE PLACE RESEARCH ASSUMES IN INDUSTRY

seeking after knowledge, or who have come under the inspiration of some teacher whose approach is of that character; but, speaking in general terms, the training of an engineer is the training of an artist or an artisan.

Let us go a step further and make the distinction under scientific research between pure science and applied science. Many think we ought not to make any distinction here. The pure scientists are likely to make the distinction of "pure" and "impure" science, and applied scientists retort by saying it is "aplied" and "misapplied" science. But there is a distinction. When one is carrying out research work, searching after truth, he is constantly coming to branch points. One branch may lead in a direction that would seem to offer the largest field for the acquisition of knowledge. It may be the most practical in the long run. It may yield the largest returns in the long run, but the other one may lead in a direction which would seem to bring the investigator more quickly to something that is of practical value, that has a commercial, a monetary significance. That difference, as I see it, between the pure scientist and the applied scientist is not one of method or training, it is one of goal. When he comes to the branch point, the pure scientist will always follow the branch that gives promise of leading to the largest returns in knowledge, the other will take the branch that gives promise of the quickest and largest commercial return.

Let us go a step further and separate pure science into what may be called frontier research, on the one hand, and intensive and co-operative research on the other. To use a figure of speech, the geographical explorer is searching for uncharted lands. He has nothing to go on but his imagination. He is scouting around on the frontier. But after he has discovered some new territory, there must come behind him a corps of men who will canvass the mineral, the vegetable and the other resources of the new territory. They are the intensive workers, they are cultivating in an intensive way the new territory which he has opened up. Consider the work of a specific laboratory, such as the Geophysical laboratory in Washington where problems of geophysics are studied intensively. Another illustration, if I may mention it, is the Nela Research Laboratory of Pure Science where the physiologist, the physicist, the chemist, the biologist and the engineer are investigating questions that have to do with lighting; it is intensive work.

The two cases cited illustrate also what I mean by co-operative research. It is not the place here to develop this idea at length, but the importance of co-operation in intensive research merits a word in passing. Much knowledge is to be found in the no man's land between the various sciences, and conspicuous progress is certain to follow intensive research in this field.

Let us now consider applied science. Under that head I have put industrial research and engineering research. I don't know just how to make the distinction clearly, but there are certain fields of work which seem to come within the scope of engineering, and in these fields there is need for research. For example, the man who undertakes the investigation of the insulation problem, which is a very live subject at the present time, has a problem and a subject matter which is of interest to engineers.

With the above as a general classification, where should these various kinds of research work be done? I would suggest that frontier research be done by universities and by privately endowed laboratories. The university man is always bringing work up to the frontier of knowledge. He has a better idea of the whole frontier, and therefore he is the man to

whom we would most likely look to push that frontier just a little further, applying imagination to the accumulated knowledge. Privately endowed laboratories may accomplish similar results, and I am thinking, as an example, of the work of the Rockefeller Institution for Medical Research. There may be fundamental work done in a laboratory of that type which would come under the category of frontier research.

For intensive and co-operative research, I have put down government, privately endowed, and corporation laboratories. Here is where the government can very well step in. Many of us would not feel that it was the function of the government, that is, of the public to support men who are browsing around for extending the margin of knowledge. Personally, I would not object to having the government undertake such work, but I believe that the men in the universities are peculiarly fitted for it. The government, however, should take a large part in the intensive co-operative research. The work of the bureau of Standards, that is, the research work that it does, fits right in here. And so it is with a large number of bureaus of the government, and properly so.

Privately endowed institutions such as the Rockefeller Institution and Carnegie Institute, are peculiarly equipped to carry on work of this kind. The university man must teach, he must read, he hasn't the time nor the inclination to keep intensively working in some special field all the time. He hasn't the equipment. His views are changing from year to year. For that work we need a corps of men that is going to stay right there on the job, work at it morning, noon and night, with their equipment permanently set up. Nine-tenths of the time is spent in getting ready; the actual observations take but a little time. After a man gets an elaborate equipment set up, he is ready usually to go ahead and investigate a great many aspects of a subject. They are constantly suggested to him. As a matter of fact, the difficulty is that we become ingrown working this way. But this very condition of continued work with the same corps of men, saturated with the idea, is the underlying one in accomplishing results in intensive research.

Intensive research in pure science should be undertaken by the government and by privately endowed laboratories, but, in my judgment it should also be prosecuted in industrial laboratories. Some 13 years ago when we organized a laboratory for pure science in the National Electric Lamp association, now the National Lamp Works of General Electric Co., it was, so far as I know, the first of the kind to be organized anywhere in the world. Most of the industrial laboratories had been admittedly applied science laboratories, but apart from any question of repaying by industry an old debt to science—an adequate reason in itself—the assumption by an industrial corporation of intensive research in pure science should also be profitable. Industrial research is ordinarily conducted in a way to give quick returns. Intensive pure science research in the field in which an industry is interested will yield a deferred return on the investment. The return must come—it is only a question of time.

Under industrial research I have suggested that it should be carried out by corporation and private laboratories. It is now an admitted function of a corporation to have an industrial research laboratory. It hasn't always been so. Germany largely has pointed us the way to that idea, and although there were some industrial laboratories—and quite a number of them—before the war, that idea has gone ahead both in this country and throughout the world with tremendous impetus since the war.

I have added private laboratories as places where industrial research should

be done, for I think that the time has come when we must have in this country industrial research laboratories of a private character. I mean privately owned laboratories to undertake research for those industrial companies which do not have their own individual laboratories. I think there should be a large field for laboratories of that kind, because it is not every company that can afford the investment and the expense of a laboratory to investigate the problems that should be investigated in that industry. It requires a large investment and it requires a large annual expense because competent men are required, and a sufficient number of them to produce a well-rounded organization.

Under engineering research I have put down government, corporation, technical school and private laboratories. They are the places where, in my judgment, we might look for that kind of research which I described a while ago as engineering research.

From these general considerations, the author has come to the conclusion that the field of research in industry embraces intensive co-operative research in pure science as well as research in applied science, and that this latter applies not only to what has been called industrial research but also to what has been called engineering research.

AN ELECTRICALLY HEATED FORGING AND HEAT TREATING FURNACE

By G. M. Little

TO GIVE a brief account of the development of a resistance type electric forging furnace, some of the problems encountered, and how they were handled is the purpose of this article.

Reasons for Development. In practically all steel manufacturing centers it is not now possible to obtain a sufficient supply of natural gas to operate continuously the various furnaces used for forging, heat treating and melting. This is most often taken care of by substituting oil during those periods of absence and shortage of gas, but this is inconvenient and expensive. The ordinary forging furnace is not adapted for producer gas, the use of which demands an expensive regenerative heating system.

Advantages of an Electric Resistance Furnace. While the lack of natural gas is an important argument for an electrically heated furnace, it is also true that higher temperatures, than can be obtained by the use of gas or oil are desirable and are easily reached in an electric furnace. An electric furnace is a much more agreeable apparatus to work with. It is quiet, does not radiate much heat, does not require frequent or extensive repairs and is capable of turning out more work than the gas-fired furnace having the same work opening.

State of the Art. When this development started no electric forging furnaces were on the market. It is true some attempts had been made to meet the severe requirements. One scheme tried was a forging furnace in which a molten salt served as the heating resistor element. The current was passed through the salt, melting it, after which the iron bars were dipped into the molten bath and soon reached a forging temperature.

Another effort was a scheme whereby the ends of the bars to be heated were dipped into water rendered conductive by the addition of certain salts. A powerful direct current of electricity was sent through the water into the bar, thus causing the water to be decomposed and a layer of white hot hydrogen gas to form on the surface of the bar underneath the water. This quickly brought the bar up to forging heat.

A great many electric arc furnaces were being used for various purposes but apparently none for forging. The low power factor, difficult regulation, and rapid consumption of the electrodes probably prevented this development. An adaptation of the induction type of electric furnace had been used for rivet heating but nothing that could be called a furnace had been evolved.

There were many carbon plate and granular carbon resistor furnaces, more particularly for heating crucibles, which gave excellent service provided that the chamber in which the resistor was located was tightly closed to prevent oxidation. In practically all of these, the furnace could not be worked or forced hard so as to heat metal quickly, as the heating element lay against the refractory walls of the chamber, and these walls were quickly destroyed.

Present Design. A consideration of this latter type of furnace resulted in efforts which have overcome the main defects so that it is no longer

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A paper presented at the Indianapolis Convention. The author, G. M. Little, is in the research laboratory, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

necessary to keep the chamber closed, and the carbon plate resistor will last some months with the working opening or door wide open all the time. This is accomplished by maintaining a reducing atmosphere or gas or oil vapor around the heating element.

Also, by the simple expedient of suspending the carbon resistor across the middle of the furnace chamber and away from the walls, the furnace can be forced considerably without damage to the walls. A further precaution was adopted in the selection of 4 x 4-inch carbon bars for the inside lining of the upper part of the furnace chamber. These bars will stand just as high a temperature as the heating element and will last a year in service, being protected from oxidation on the lower side by the same reducing atmosphere that surrounds the heating element, and on the upper side by a layer of carbon dust, which is slowly consumed, and has to be replaced at long intervals.

General Description. The furnace in its final form consists of a cast iron box about 4 feet long x 3 feet deep and 4 feet high, mounted on cast iron legs about 30 inches high. In the front side of the box is the familiar long narrow opening into which the iron bars are introduced, just as in the standard gas or oil-fired furnaces. At the sides are located water cooled bronze terminals and the copper leads by which the current is brought to the furnace.

The inside of the box is lined heavily with refractories and heat insulation, leaving space only for a chamber 30 inches long, 9 inches deep and 20 inches high. Reaching full length across the upper part of this chamber, but nowhere approaching the walls nearer than 3 inches is suspended the heating element. A small stream of natural gas is fed up through an opening in the floor into the furnace chamber continuously. This causes a small flame and some smoke to escape lazily from the upper edge of the opening, and a chimney connection has been provided in case this should be in any way objectionable.

Provision has been made in the back of the furnace to allow the brick work to be removed so that repairs to the heating element can be made readily. Wind shields are placed at the sides of the working opening which in some degree prevent the action of air draughts in the room, which tend to blow the protecting gas out of the chamber. The furnace takes from 16 to 40 kilowatts depending upon the size of the iron bars being heated and requires little regulation, hand control being found satisfactory.

Selection of the Heating Element Material. It is absolutely essential in a forging or melting furnace to be able to crowd or push it so that a large amount of metal can be brought to the desired temperature quickly. It was obvious then that any heating element would have to fulfill the following conditions:

(1) It must have a large radiating surface in order to radiate a large quantity of heat. (The filament of a tungsten lamp operates at a very high temperature, but does not radiate much heat).

(2) It must be strong at all temperatures as it may be subjected to shocks and jars from nearby steam hammers in the forge shop.

(3) It must not be injured by being operated at very high temperatures —probably up to and over 3000 degrees Cent.

(4) It must have a reasonably long life.

(5) It must be renewed easily.

(6) It must not be expensive.

(7) Its change in resistance due to change in temperature must not be very great.

Resistor Materials Other Than Carbon. A consideration of the above conditions and a survey of some of the materials which might be used resulted decisively in eliminating all except carbon.

(1) The rare earths such as are used in the Nernst lamp are expensive, are frail, and are insulators when cold.

(2) Nichrome will melt at the high temperature demanded.

(3) Tungsten is expensive and might melt or oxidize.

(4) Metallic oxides and sulphides will be melted or decomposed.

(5) Carborundum looked hopeful but it was found that great difficulty was encountered in starting the furnace cold, that no two resistors

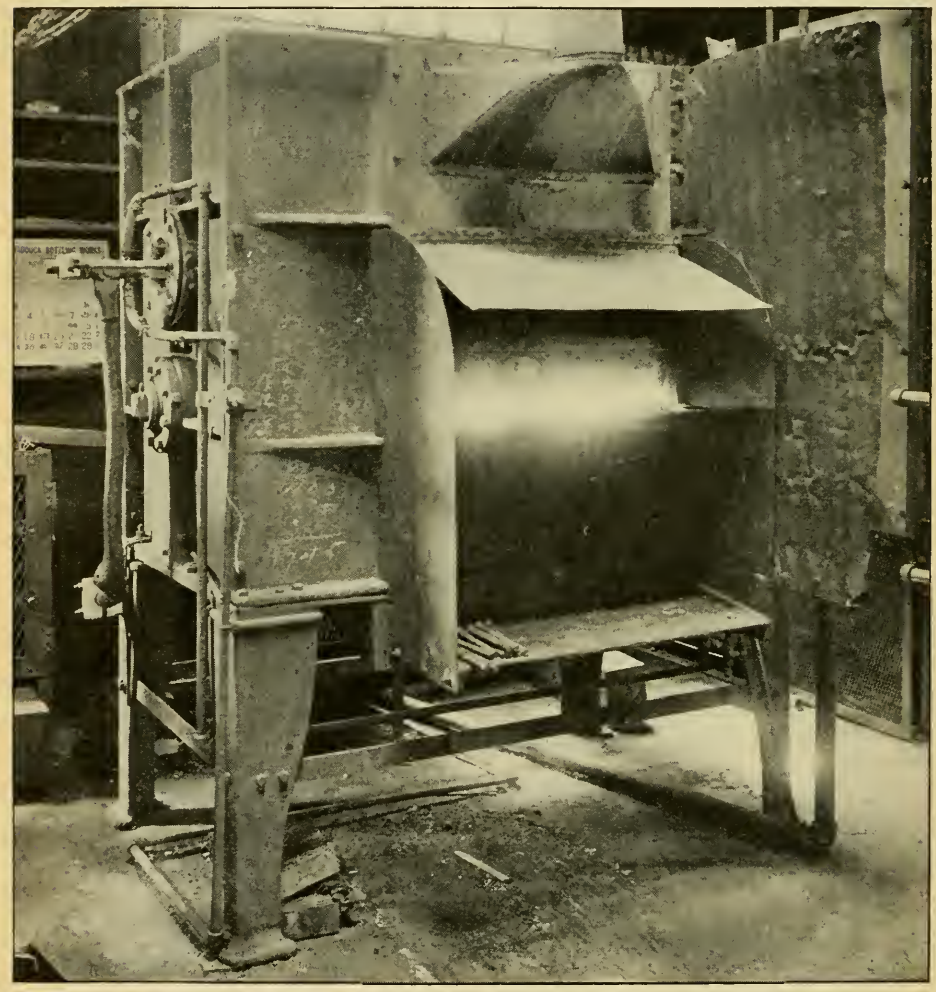

FIG. 1—FRONT VIEW OF RESISTANCE TYPE ELECTRIC FORGING AND HEAT TREATING FURNACE

were alike, and that they were apt to crack in two and start arcs which would destroy them. Carborundum decomposes at 2250 degrees Cent.

Carbon in some form appeared to be the only possible substance to consider. Graphite crucible material, which contains a large per cent of carbon and of kaolin was tried unsuccessfully. Granular carbon as ordinarily used would not do as it requires a supporting wall or trough of insulating refractory material and if the furnace were pushed, the supporting refractory wall or trough would be destroyed. It also has a most variable resistance in service. A carbon rod of practical size and strength used as a resistor would have such a low resistance as to require the use of an excessive current, necessitating very large copper leads.

A satisfactory result was obtained by the adoption of a heating element composed of a pile of carbon plates held together by a strong spring pressure which was applied to the ends of the pile. This complete heating element would handle over 100 kilowatts safely and cost only a nominal sum. About the only serious defect this carbon plate resistor had, was that it would be rapidly consumed if any air or water vapor came in contact with it while it was red hot.

Mechanical Means for Protecting the Carbon Plates from Oxidation. The most obvious remedy was to coat the surface of the resistor with some refractory glaze, however, there was no glaze that would stand the temperature. Burying the resistor in coke dust was effective against oxidation but was not suitable in other ways. Of course, the carbon heating element would last indefinitely in a vacuum, but this condition was impossible.

Protection by Means of Gases. The use of a surrounding atmosphere of inert gas, looked promising and a mixture of nitrogen and carbon monoxide, obtained by passing air through red hot carbon, was tried. This did protect the resistor considerably but did not give as satisfactory a result as was obtained by the use of hydrocarbon vapors, natural gas or oil, which not only prevented the action of oxygen on the resistor, but actually built on a little film of carbon just as is done in the "flashing" process in the manufacture of carbon incandescent lamp filaments. In this process thin spots in the white hot filaments are thickened by an accretion of carbon from the surrounding gasoline vapors.

Materials for Producing the Protecting Vapors. The hydrocarbon vapors may be introduced into or produced in the furnace chamber in several ways. Gas is easiest to handle and is, of course, ready to start its protecting action immediately. Oil has been used satisfactorily and other materials such as powdered coal or sawdust, if fed into the hot furnace, will give off their protecting vapors which will rise into the upper part of the chamber. It has been found that by this means the carbon heating element and carbon roof can be made to last for long periods, the resistor for several months and the roof for a year.

Means of Introducing the Hydrocarbon Vapors. The first experiments were made with natural gas which was introduced through a 1-inch carbon pipe projecting through the roof of the furnace. It was found that the pipe would soon choke up constituting an occasion for a difficult repair. A simpler and all round better scheme was to introduce the gas at the working opening or through the furnace floor where the pipe was at all times under observation and could be cleaned easily and quickly when necessary.

Gas Does Not Necessarily Fill the Entire Chamber. In the present design of furnace the working opening is near the bottom of the furnace chamber and any excess of gas escapes at the level of the top of this open-

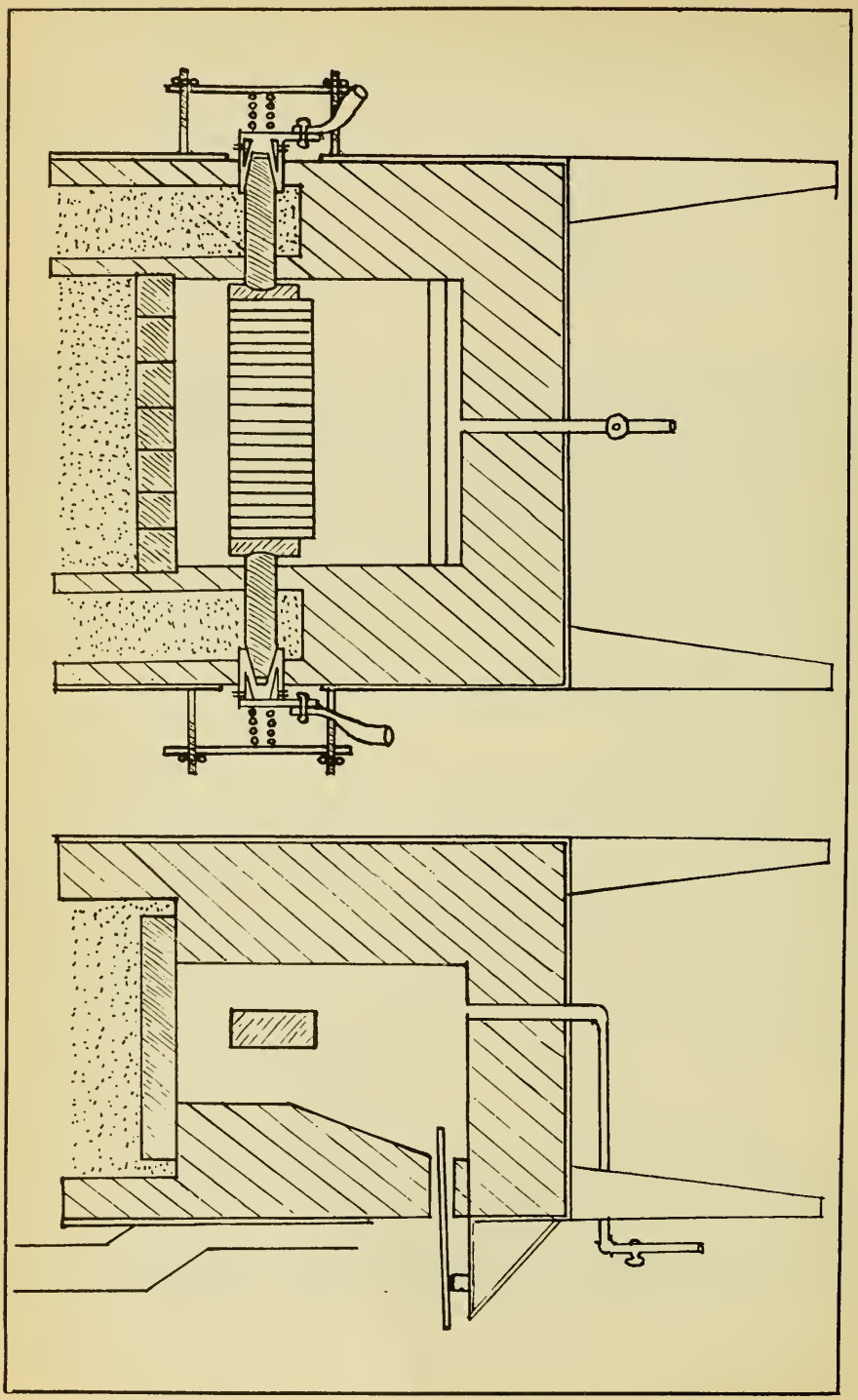

FIG. 2—TRANSVERSE AND LONGITUDINAL SECTIONS OF ELECTRIC FORGING AND HEAT TREATING FURNACE

ing—below that level the atmosphere in the furnace chamber is oxidizing. If, for any cause the supply of gas is shut off or is insufficient, it takes only about 100 cubic feet per day, the heating element is attacked by the inleaking air, most rapidly at the bottom and soon is consumed.

Oil. While it is advisable to use gas, when it can be obtained, to maintain the necessary reducing atmosphere in the upper part of the furnace chamber, it might sometime be necessary to use oil, and a variety of means of feeding it to the furnace were tried. The most successful scheme was to squirt the oil intermittently, a few drops at a time, from a fine jet mounted about 1 foot away from the working opening. The motor-driven pump had a 1/4-inch diameter piston and ⅛-inch stroke. This piston was raised slowly against a powerful spring pressure by means of a cam, at the top of its movement the cam released its hold and the springs vigorously forced the piston down, causing a few drops of oil to be thrown violently well into the furnace chamber. It was necessary to use about 1 gallon of oil in 24 hours. Heavy oils worked best.

Means of Obtaining a Relatively High Resistance in the Heating Element. Having decided upon the use of carbon plates, the size and thickness of the individual plates as well as the overall dimension of the assembled heating element were considered, and for a tryout, plates 6 inches long, 2½ inches wide and 1/4 inch thick were made up into two piles, each 15 inches long. These were clamped in the furnace chamber in series and held under about 200 pounds pressure. Natural gas was run into the chamber and the current turned on, about 50 kilowatts being used.

This first tryout was very successful. The furnace was kept up to a forging temperature for nearly six weeks. One undesirable feature brought out was the fact that on account of the low resistance of the heating element, a large current, 2000 to 2400 amperes was required to produce the necessary heating effect.

It was evident that the resistance could be increased a number of ways: (1) Thinner plates and more of them would give an increased number of resisting contacts in series; (2) have plates formed with projecting contact areas, which areas could be made as small as desirable; (3) make pile of plates of alternate full sized plates and small plates; (4) make the pile of plates of alternate full sized plates and granular carbon; (5) use a longer pile of plates; (6) use plates of smaller area; (7) have plates made from a form of carbon having a specifically higher resistance. All of these have been tried and all in some degree accomplished the desired change, though so far the best results have been obtained by using alternate full sized plates and small plates. By this means the current normally required has been reduced to about 1000 or 1200 amperes.

Renewal of the Heating Element. Two means of entering the furnace chamber are provided, through the top and through the back. If the furnace be allowed to cool down for 48 hours it is a simple matter requiring about two hours time to remove the top heat insulation and refractory lining, put in a new heating element, and put back the heat insulation and refractory lining. This is the method that has been used up to the present. It is probable that the renewal could be accomplished without waiting for the furnace to cool, by opening the back wall, holding a new heating element supported on a tray between the ends of the graphite electrodes, then tightening the springs and replacing the brick work. A removable section has been provided in the iron work to permit this to be done.

Furnace Lining. In this furnace, it is necessary that the heating element

be located in the upper part of the chamber where it is well protected by the blanket of gas from any inleaking air. From this it follows that the upper part of the chamber is by all means the hottest part of the furnace and for that reason it has been found advisable not to use in this zone the ordinary refractories such as fire brick, beauxite or magnesite, but to use for a lining, heavy carbon bars laid close together and covered with carbon dust. These carbon bars can not be melted and if protected from oxidation by means of the blanket of gas in the furnace chamber will last a year. The upper side walls are lined with carborundum brick which stand severe punishment quite well, so long as they do not have to carry current. The lower parts of the chamber where the temperature is kept down somewhat by the continuous introduction of iron bars, etc., may be lined with fire-brick. All these furnace linings will last much longer than do linings of gas-fired furnaces, owing to the absence of the cutting action of the blast.

Terminal Connection. Some unexpected trouble was experienced in that the 3-inch round graphite electrodes which serve to carry the current through the walls would burn in two in the middle of the wall. This has been prevented by making the wall hollow, where the graphite electrodes pass through, and filling in the space around the electrodes with coke dust.

Satisfactory contacts between the heating element and the graphite electrodes are accomplished by rounding the end of the electrodes which project into the furnace chamber, and providing hollowed out sockets in the graphite blocks which form the end plates of the heating element. This constitutes a ball and socket joint which allows a little movement should the shrinkage of the walls or heating element demand it. The water-cooled external connections are designed so as to permit several inches forward movement of the graphite electrodes to allow for shrinkage of the heating element. They are also fitted with a powerful spring and screw adjustment to keep the plates under heavy pressure. The water-cooled connections give no trouble and do not absorb much energy.

Heat Insulation. In any electric furnace, heat insulation is of vital importance. In this furnace, it has been found advisable to back up the inner refractory lining of carborundum, or fire brick with a layer of fire brick and then with two outer layers of high grade insulating brick next to the iron shell. The heat insulation on top consists of a layer about 6 or 8 inches deep of coke dust on which rests one or two layers of high grade insulating brick. The result of this design is that the radiation loss is small.

Control. The control of the furnace is exceedingly simple. The current is 25 cycle, single phase and is drawn from a 37-kilowatt transformer having six taps, making available voltages from 60 down to 20. When a new heating element is put in service, it has a high resistance and a start is made on the 60-volt tap. As the furnace heats up the resistance becomes lower, partly because of the negative temperature coefficient of carbon and partly because a thin dense layer of carbon deposits from the gas on the outside of the heating element. The plates also become fitted together much more perfectly under the influence of the high temperature and high pressure. This lowering of the resistance, which is unavoidable, is compensated for by changing the transformer connection to one of the lower voltage taps. After the first two days, the changes in resistance take place slowly and if the work is fairly steady, the furnace will run for days at a time on a single tap.

Several schemes for automatic temperature control have been worked upon but it has not been found necessary for forging operations to use.

anything but hand control. A furnace was operated continuously heading bolts for five months this way. As an illustration of the ease of operation, it may be said that through the day this furnace was operated with the writers' knowledge and care, but through a misunderstanding, it was also operated each night without his knowledge and with no special directions having been given the workman who experienced no trouble. One of the desirable features of this furnace is the high power factor which is probably in the neighborhood of 95 per cent.

Cost of Operation. The greatest expense is of course the cost of the current, which varies considerably in price in different locations. With this information furnished, the cost of operation may be readily figured since the furnace requires from 16 to 22 kilowatts for medium sized and small iron bars and perhaps up to 40 kilowatts for larger work. As a rule, the cost of current is less at night so that even though the furnace is not used at night it may yet be desirable to keep a little current flowing, but if this is not

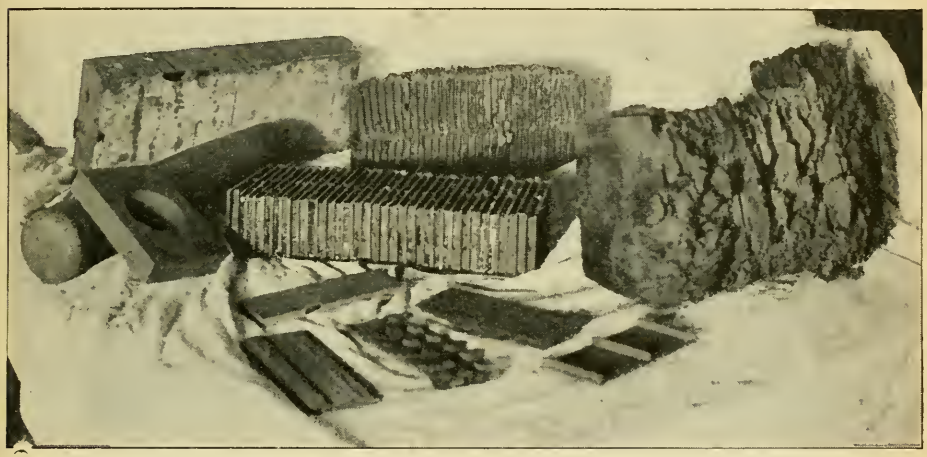

FIG. 3—CARBON ELECTRODES AND TERMINAL CONNECTORS USED IN THE FURNACE

done, the furnace may still be brought up to heat rapidly in the morning by crowding it for an hour or so.

The renewal of the heating element is expected to occur not oftener than once in three months at a nominal cost for materials and two hours time. The refractory lining is expected to last in the neighborhood of a year. It is expected that the upkeep and repairs will be much less than with gas-fired furnaces. One item which tends to reduce the cost of operation per pound of metal heated, is the fact that the furnace may be run at a higher temperature than the gas-fired furnaces and the bars of iron can be rushed through faster.

Future Development. The work in the past has been mostly directed toward producing a forging furnace, but a muffle-type calcining furnace has been started and a small experimental brass melting furnace using a carbon plate heating element was built This brass melting furnace gave some interesting results. It was seen that with 50 kilowatts it was a simple matter starting with cold pigs, to melt and pour 100 pounds of brass in 15 minutes.

The bath of metal could be subjected to either oxidizing or reducing conditions at will. The zinc loss was very small.

There was not the tendency to intense local heating ordinarily found in arc furnaces. No trouble was encountered in shutting down and starting the furnace cold. The entire charge could be poured at each heat. It was also found that steel could be melted readily in this furnace without damaging the heating element or other parts.

CARBURIZING HEAVY SECTIONS

By W. I. McInerney

AS MOST of the papers on carburizing presented before meetings of the society have dealt with surface carburizing, a short paper on some of the methods and results obtained in deeper carburizing, that is, in a measurable increase in the carbon content of the section from the surface to a depth of 2 inches should be of interest. The process of carburizing, or as it is sometimes called carbonizing or cementing though the term carburizing is the generally accepted term as applied to heavy sections, is probably more extensively used in the manufacture of armor plate than any other branch of the steel industry.

Modern practice requires a carburization for a depth of one inch or more, and to get the proper graduation from the surface to the required depth, and not get excessive concentration in the surface strata is the problem that confronts the heat treater, and the carburizing compound manufacturer.

The theory of carburization which is usually brought forth as an introduction to such a paper as this, is familiar to all, as are also the different tables on the acceleration and retardation of the different elements and the percentages of times necessary to add or subtract when using steels of different compositions. For the purposes of this paper the compositions of the steel was practically the same in all cases except as noted.

Of the three carburizing agents, namely liquid, solids or gaseous, the solids have been more extensively used than either of the other two. There are certain requirements that must be met by the carburizing agent before it will prove satisfactory for use in this particular line, a few of which are:

1. Uniformity as to composition and physical qualities, grain or pellet size.
2. Freedom from sulphur in injurious amounts less than 0.5 per cent.
3. Freedom from internal combustion.
4. It should not flux or fuse at any temperature up to 2100 degrees Fahr.
5. It should not coke or cake on the plate making it difficult to remove.
6. It should also have a good bearing value and minimum shrinkage so as not to crush excessively in use.

Home made carburizers have not proven any more economical than the commercial ones, and are not as satisfactory due to the difficulty in properly mixing them and the liability of infringing on already patented compounds.

The practice from which the accompanying results were obtained differs considerably from the usual run of carburizing in that no pots, boxes or other containers are used. A plate to be carburized is forged

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to thickness somewhat in excess of the final thickness, then after proper heat treatment which usually consists of annealing to prevent cracking in the subsequent cooling after forging and the reheating to carburize, it is prepared for carburization. After removing all surface scale, any seams or tears are chipped out so that when the final forging is completed after carburizing a smooth even surface will be obtained and the necessity of machining eliminated.

Where a superficial depth of carburization is sufficient, that is to approximately a depth of ⅛ or 3/16-inch from the surface, the plate is first preheated to a temperature of 1500 degrees Fahr., taken out of the furnace and the carburizer spread on the hot plate for a depth of 2 inches or more and a layer of some refractory, usually dry yellow clay, sifted through a ¼-inch mesh, is put on top of this for a depth of 3 inches or more. The thickness of both layers depends on the depth of carburization desired. The plate is then recharged and the heating continued, temperature and time governing the depth and amount of carbon absorbed.

The carburizer used in this practice must be such that it will not burn up as soon as it is spread on the hot plate; it must not flux or stick to the plate when dumped off and should be uniformly active from the start to the finish of the run. In heavier sections where a greater depth of carburization is required, the plates are put together in pairs, sandwich fashion, that is the surface of one of the plates which is selected to be carburized has either a brick wall, one or two courses high, built around its edge or an angle iron frame is substituted. The purpose of either brick or angle frame is to form a recess or separation between the upper and lower plates which contains the carburizing material.

Usually when four such pairs of plates are prepared they are charged two pairs in tandem on a car-bottom furnace, the latest types of which have a car bottom 15 feet wide and 52 feet long, and are designed to carry a load of 600 tons. It is not unusual for an average load of eight plates to total 500 tons.

An experiment to determine the rate of carburization was made using 10 pieces 4 x 12 x 24 inches, one piece being withdrawn from the furnace every 24 hours, and the increase of carbon determined for each 1/16-inch from the surface with the following results:

Temperature 1870 degrees Fahr. Base carbon 0.28 per cent

		Per cent of carbon at various depths				
Piece No.	Hours	1/16 inch	¼inch	½ inch	1 inch	1½ inch
1	24	0.93	0.60	0.40	0.29	0.28
2	48	0.94	0.62	0.53	0.30	0.28
3	72	0.95	0.64	0.54	0.31	0.28
4	96	0.95	0.67	0.57	0.33	0.29
5	120	0.96	0.68	0.59	0.34	0.30
6	144	0.97	0.71	0.61	0.35	0.32
7	168	0.97	0.73	0.63	0.37	0.33
8	192	0.98	0.75	0.65	0.38	0.34
9	216	0.99	0.78	0.67	0.41	0.34
10	240	1.00	0.80	0.69	0.42	0.35

In the lighter sections up to 5 inches in thickness, a sufficient depth of carburization can be secured during the heating for final forging,

after preheating to 1500 degrees Fahr. and covering with the carburizer, heating is continued with the following average results:

Preheating previous to covering—12 hours
After covering to reach forging temperature—10 hours
Soaking at forging temperature—24 to 30 hours
Average base composition—Carbon 0.50, chromium 2.10, and nickel 3.50 per cent
Per cent of carbon at various depths

1/32 inch	1/16 inch	⅛ inch	¼ inch
0.90	0.98	0.80	0.60

A comparative experiment using four different commercial carburizers between two sections 12 inches thick, gave the following results:

Average base composition—Carbon 0.32, chromium 2.36 and nickel 3.66 per cent
Temperature held at 1925 degrees Fahr.

	Per cent of carbon at various depths.			
Mixture No.	1/16 inch	⅛ inch	½ inch	1 inch
1	1.24	1.22	0.84	0.52
2	1.55	1.47	0.97	0.50
3	1.36	1.32	0.88	0.53
4	1.20	1.17	0.78	0.51

After further investigation mixture No. 1 was selected as the best for the purpose intended.

Another experiment with two commercial carburizers to determine the effect of prolonged holding at a temperature of 1970 degrees Fahr. gave the following results:

Average base composition—Carbon 0.48, chromium 2.35, and nickel 3.84 per cent
Time to reach temperature—100 hours or 4 days 4 hours
Time held at temperature—484 hours or 20 days 4 hours

	Per cent of carbon at various depths								
Material No.	1/16 inch	⅛ inch	¼ inch	½ inch	¾ inch	1 inch	1¼ inch	1½ inch	2 inch
1	2.20	2.04	1.61	1.35	1.14	0.91	0.78	0.65	0.50
2	1.87	1.67	1.45	1.34	1.12	0.92	0.71	0.62	0.49

The practice of firing back before stripping after the completion of the carburizing treatment has not been put into regular use as whatever points that have been claimed for it are offset by the additional furnace time required. The usual practice on heavy sections is to strip the furnace after the required time has elapsed, the carburizer is dumped off and the heavy scale which forms on the exposed areas falls off and the face, or carburized surface, of the plate which has cooled in the meantime to about 1500 degrees Fahr., is covered with a protecting layer of buckwheat coal and a layer of dry yellow clay and heated for final forging.

THE FUTURE FUEL FOR THE HEAT TREATMENT OF STEEL

By H. O. Loebell

HEAT treatment of steel is essentially and primarily a heat operation and therefore the introduction and utilization of the most desirable fuel is a problem of prime importance to the industry. This article does not consider the physical, mechanical or metallurgical aspects of heat treatment, but deals with the introduction, utilization and application of a fuel which will permanently solve the heating problem.

Important fuels of today are fuel oil, pulverized coal and industrial manufactured gas. Fuel oil is a desirable fuel but because of insufficient supply we cannot consider it as a future fuel for our industry. Some years ago fuel oil was selling at 2½c per gallon and could be obtained in any desired quantity. Today fuel oil is selling from 12c to 15c per gallon and in many cases cannot be obtained at any price. Fuel oil consumers are now on the lookout for another fuel. This condition brings out the important fact of considering the permanency of a fuel. Millions of dollars will be spent on future furnace construction and installation and we must therefore consider a fuel which will be permanent and which will continue to serve the industry in the future. Powdered coal is desirable in many cases but this fuel is only an intermediate development in the final solution of the problem. Ultimately we realize that our enormous coal resources will be treated in such a fashion that we will obtain all the valuable materials from a ton of raw bituminous coal. We can obtain 20 million B.t.u. in a form most desirable for heating operations and also 20 gallons of fuel oil and 20 pounds of ammonia. Furthermore, the ash of pulverized coal is a destructive agent. The fusion of this ash in the furnace attacks the furnace lining to such an extent that it would be necessary to shut down and make repairs too often for satisfactory continuity of operation.

Today it is an established fact that the most flexible and efficient heating medium is a gaseous fuel. The bituminous coal resources are practically inexhaustible and they will therefore act as a raw material for the production of a fuel which will be permanent. From this coal we can make a gas which is efficient and desirable and at the same time obtain all the valuable by-products that are in the coal. Such a fuel besides being permanent will never be prohibitive as far as price is concerned as methods of gas production, distribution, and utilization are always becoming more efficient. Therefore, the price of a gaseous fuel would have a tendency to decrease.

The essential advantages of a gaseous fuel are well realized. In the first place it permits flexible furnace design, that is, from a consideration of the nature of the product, the furnace can be designed in any way that is deemed necessary and the fuel can be applied in any manner which the particular type of furnace demands. With the gaseous fuel ash is eliminated and no storage space is required. The gas is piped to the furnace and its application is only dependent upon the turn of a valve. With this fuel the most efficient combustion is obtained with the least amount of excess air. The control of furnace temperature is essential to good heat treatment and the temperature of a gas furnace is very easily

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controlled. At a large plant in Toledo, carbonizing furnaces heated with gas have a temperature control varying only 10 to 15 degrees.

Assuming that gas is the ideal industrial fuel the following questions may be asked. Will any kind of manufactured gas be suitable for steel heat treatment, and if not, which gas has the required physical and chemical properties to adapt itself to practically all heating operations? To realize the possibilities of an industrial gas requires a careful study of its physical and chemical properties, the most important of which are as follows:

1. Theoretical flame temperature.
2. Thermal value.
3. Chemical composition.
4. Rate of flame propagation.
5. Ignition temperature.

Table I

Properties of Important Industrial Fuels

Number	Kind of Gas	Constituents of Gas—Per Cent by Volume									B. T. U. per Cu. Ft. Gas 60 Degrees Fahr.	Cu. Ft. Air per Cu. Ft. Gas for Combustion	Products of Combustion per Cu. Ft. Gas	Theoretical Flame Temperature Degrees Fahr.	B. T. U. per Cu. Ft. Products of Combustion 60 Degrees Fahr.
		CH_4	C_2H_6	C_2H_4	CO_2	CO	H_2	O_2	N_2	H_2O Vapor					
1	Blue Water Gas	2.0	..	...	4.0	45.0	45.0	0.5	2.0	1.5	313	2.32	2.88	3595	108.5
2	Blue Water Gas	2.0	..	...	6.0	38.0	48.0	0.5	5.5	...	300	2.24	2.81	3580	107.0
3	Carbureted Water Gas...	25.0	..	8.5	3.0	19.0	40.0	0.5	4.0	...	563	5.06	5.77	3510	97.5
4	Manufactured Coal Gas....	40.0	..	4.0	0.5	6.0	46.0	0.5	1.5	1.5	626	5.64	6.37	3510	98.5
5	Coke Oven Gas	33.95	..	5.15	2.56	6.08	47.88	0.6	3.8	...	600	5.24	6.00	3555	100.0
6	Producer Gas, Hard Coal Using Steam.	...	..	...	5.0	25.0	20.0	0.5	49.5	...	146	1.08	1.86	3020	78.5
7	Producer Gas, Soft Coal....	3.0	..	0.5	5.0	23.0	10.0	0.5	58.0	...	145	1.13	1.98	2860	73.0
8	Producer Gas..	4.68	..	0.15	9.1	14.1	9.62	0.33	62.2	...	127	1.03	1.91	2570	66.5

The theoretical flame temperature of a gas is the maximum temperature that can be obtained. In practice this is never realized due to slow combustion, incomplete combustion, radiation and over-ventilation losses, and various minor conditions. The higher the gas flame temperature, the greater the differential temperature between the gas and the material in the furnace, which results in greater heat transfer and greater production per unit time. By thermal value of a gas is usually meant the B.t.u. content per cubic foot at 60 degrees Fahr. However, the thermal value that actually counts is the thermal value per cubic foot of burned gas, because the heating is done by the heat in the burned gas. The more heat per cubic foot of burned gas or products of combustion, the greater is the heat available for heating the material.

By varying the chemical composition of a gas, many of the factors of the efficient utilization of the fuel can be varied. For instance, if a gas contains appreciable amounts of hydrocarbons, it cannot be preheated before burning as the hydrocarbons would decompose and eventually

clog up the preheating apparatus. Then again, the rate of flame propagation and the ignition temperature depends on the chemical composition of the gas. A gas that contains small amounts of hydrogen requires a high ignition temperature and has a corresponding low rate of flame propagation. A gas of this kind burns slowly with a long flame and therefore requires a relatively large combustion area for the liberation of a given number of heat units. On the other hand, a gas with a high hydrogen content requires only a low temperature for ignition; the rate of combustion is very rapid, and relatively speaking, only a small combustion area is necessary for the liberation of a given number of heat units. Because of its high hydrogen content, blue water gas has the highest rate of flame propagation of any industrial gas. This is a decided advantage because a relatively large number of heat units can be liberated per unit volume of combustion space and thus a smaller combustion space is required than for other industrial gases. In Table I are shown the various properties of the most important industrial gases.

In judging the merit of an industrial gas by its B.t.u. value per cubic foot, it would be found that manufactured coal gas of a 626 B.t.u. value would be the best; blue water gas with a B.t.u. of 300 would be second, and producer gas would be third. These gases do not rank in this order, however. To judge correctly the merit of a gas by its heat content we must realize exactly what takes place during combustion. When a gas is burned, the heat developed is utilized immediately to heat the products of combustion or the burned gases. The burned gases give up their heat to the furnace walls and materials in the furnace. Thus the true source of the heat is the heat in a unit volume of the products of combustion. Also the flame temperature is directly proportional to the heat units in a cubic foot of the burned gases. The more B.t.u's supplied per cubic foot of products of combustion, the higher will be the flame temperature. This shows that not only are more heat units available but a greater temperature differential is secured between the flame and furnace material, and therefore causes a greater rate of heat transfer from the gas flame to the material in the furnace.

For the combustion of 1 cubic foot of coal gas of 626 B.t.u. value is required 5.64 cubic feet of air. The volume of the products of combustion is 6.37 cubic feet. From this is obtained the B.t.u. content per cubic foot of the products of combustion, which is 98.5 B.t.u.'s. By knowing the specific heats of the various gases in the products of combustion, the theoretical flame temperature is found to be 3510 degrees Fahr. With 1 cubic foot of blue water gas of a 300 B.t.u. value, 2.24 cubic feet of air is required for combustion. The volume of the products of combustion per cubic foot of gas burned is 2.81 cubic feet. From this it is found that the heat in 1 cubic foot of the products of combustion is 107 B.t.u., and the theoretical flame temperature is 3580 degrees Fahr. With a producer gas of a 145 B.t.u. value per square foot is required 1.13 cubic feet of air for combustion. The products of combustion for 1 cubic foot of gas burned amount to 1.98 cubic feet. Calculating as in the previous cases, it is found that the heat in 1 cubic foot of the products of combustion is only 73 B.t.u.'s and the flame temperature is 2860 degrees Fahr. From this chart, therefore, it is observed that blue water gas contains more B.t.u.'s per cubic foot of products of combustion and has a higher flame temperature than any other industrial gas. This shows that per cubic foot of burned gas, blue water gas has both more heat content and

greater heat intensity than any other industrial gas. This means greater heat transfer, greater production and higher efficiency.

Because the fuel and air are preheated to obtain a high working temperature and also to obtain a better thermal efficiency, let us consider the theoretical flame temperature of these different fuels using varying preheating temperatures for the air alone and for the air and gas. Curves of this data show that blue water gas has the highest flame temperature.

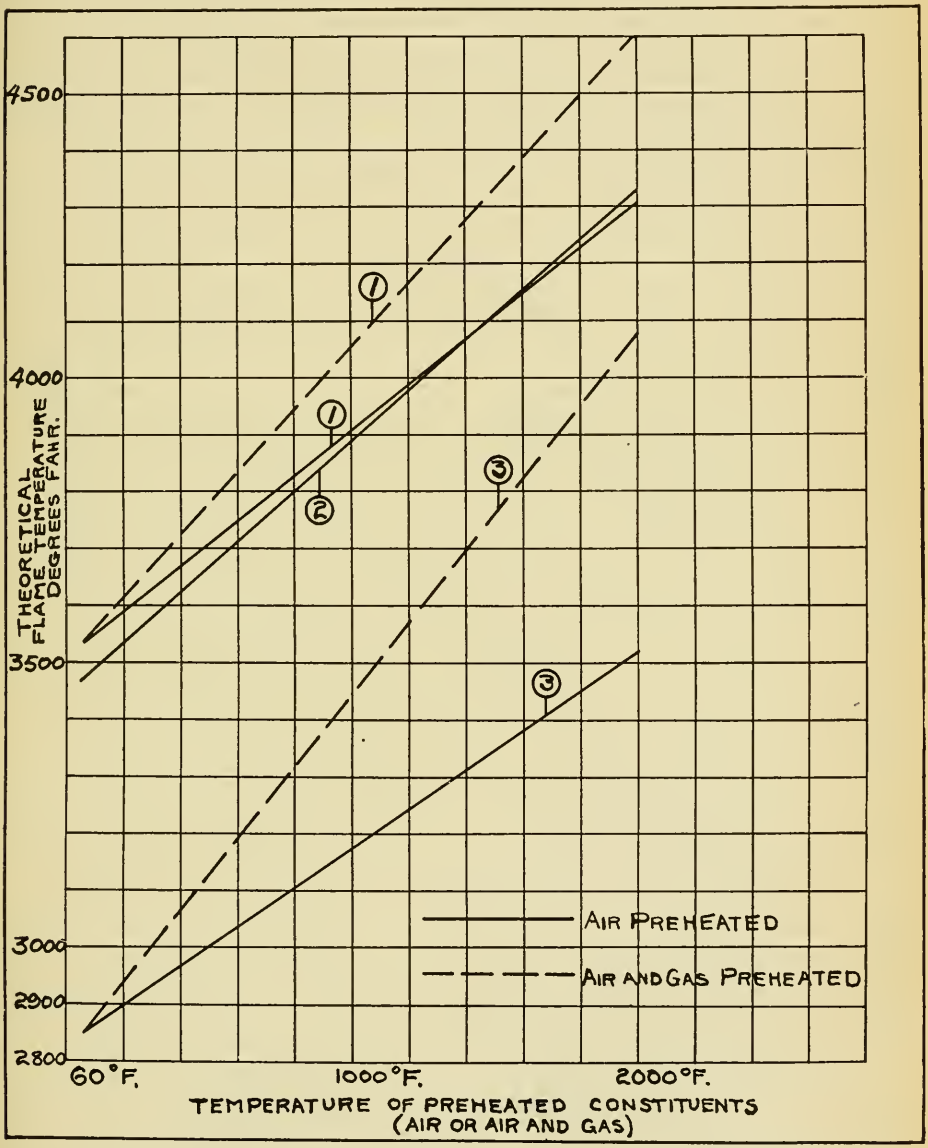

Fig. 1—Theoretical Flame Temperatures of Various Gases, Air Preheated and Air and Gas Preheated. Curve No. 1 is for Blue Water Gas of 300 B.t.u. No. 2 is for Carbureted Water Gas of 560 B.t.u. and Manufactured Coal Gas of 600 B.t.u. Manufactured Coal Gas Cannot Be Preheated. No. 3 is for Producer Gas of 145 B.t.u.

This fact is an important item in increasing the efficiency of the furnace and increasing production. As an illustration suppose we were to burn blue water gas and producer gas in identical furnaces, having the gas and air for combustion preheated to 1000 degrees Fahr. The theoretical flame temperature of the producer gas would be 3450 degrees Fahr., and if we had an operating furnace temperature of 2500 degrees Fahr., we would have a differential between the flame and the furnace of 1550

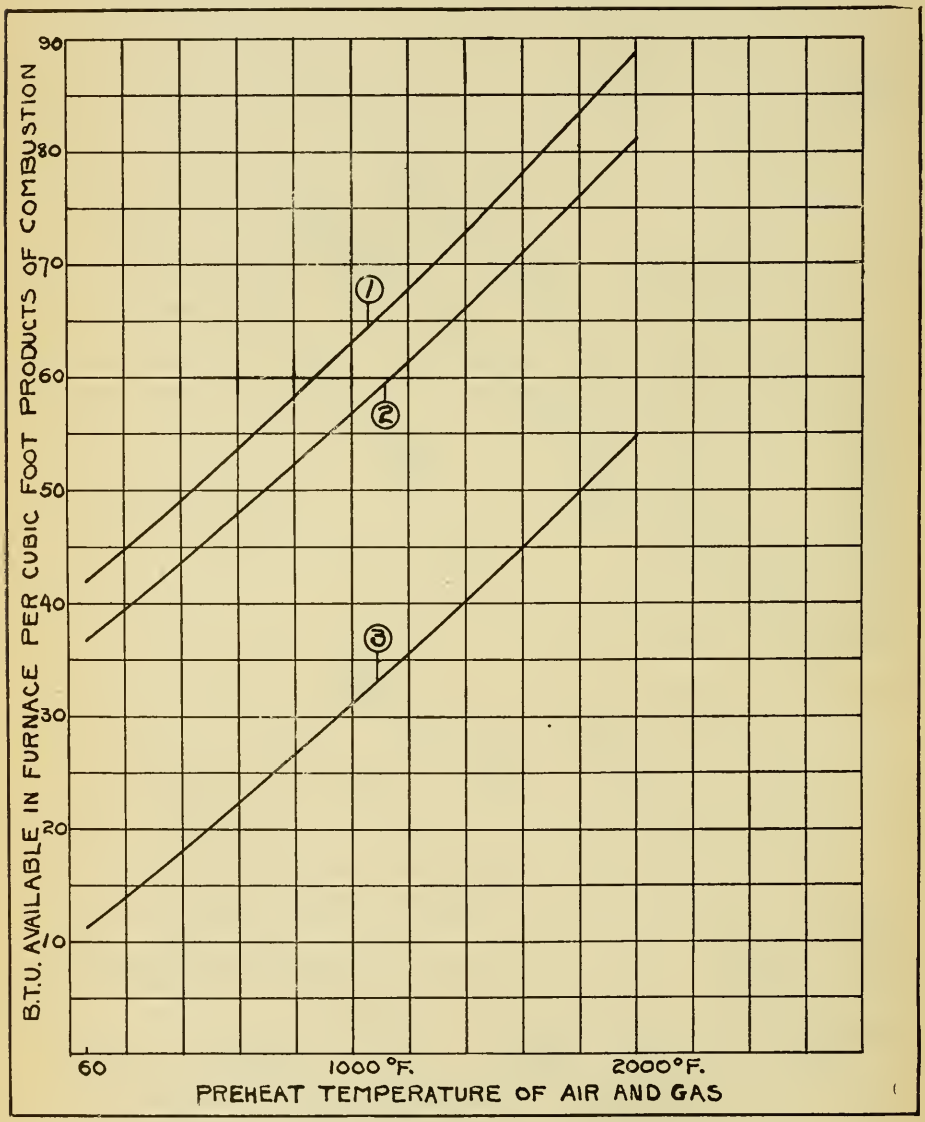

Fig. 2—B.t.u.'s Available in Furnace Per Cubic Foot Products of Combustion, Flue Gases Leaving Furnace at 2500 degrees Fahr. Curve No. 1 is for Blue Water Gas. No. 2 is for Manufactured Coal Gas. Since This Cannot Be Preheated, a Higher Preheat Temperature is Obtained on the Air. No. 3 is for Producer Gas

degrees Fahr. for blue water gas and 950 degrees Fahr. for producer gas. By having this greater differential using blue water gas greater production and better efficiency is obtained than by using producer gas under similar conditions.

In Fig. 1 is considered the gases from a flame intensity standpoint and in Fig. 2 is considered these industrial fuels from a heat content standpoint per cubic foot of products of combustion. In the latter case, blue water gas has the greatest heat content under any condition of preheated air and gas. Using blue water gas and producer gas in identical furnaces with the air and gas preheated to 1000 degrees Fahr. and flue gas leaving at 2500 degrees Fahr., 63 B.t.u. is available using blue water gas and only 31 B.t.u. using producer gas per cubic foot of products of combustion. In other words, under these conditions about twice as many B.t.u.'s per cubic foot of products of combustion is obtained using blue water gas than is the case when using producer gas. This means that at least twice as much work can be done with the furnace using blue water gas than with the furnace using producer gas per unit time, and since the heat losses per unit time are about the same for both furnaces, a much greater thermal efficiency is obtained on the furnace using blue water gas. From these curves it is seen that as far as chemical and physical characteristics are concerned, blue water gas is by far the better gas.

The fact that a large number of producer gas plants are in existence is no argument against the use of blue water gas or any gas made from coal where all by-products are recovered. The producer gas plant is a part of the industrial institution of the past and only cheap and abundant fuel is justification for its use. One advantage of a gas producer is that a wide range of fuels can be gasified. In fact, almost any kind of carbonaceous material can be converted into producer gas if it does not carry too much water or is not too greatly diluted with noncombustible material. The gas formed, however, may be difficult and uneconomical to use. Although producer gas is the cheapest gas which can be made per B.t.u. at the present time, yet its dilution with inert gas and its chemical characteristics greatly diminish its attractiveness as an industrial fuel.

To substantiate our theory and to show the advantages of a gaseous fuel, particularly a gas with a high flame temperature such as blue water gas, the results of several installations made during the past few years will be given. In comparison with fuel oil the following results have been obtained. Under the best conditions of oil utilization it has been found that 5½ gallons of 142,000 B.t.u. oil can be replaced by 1000 cubic feet of a 600 B.t.u. manufactured gas. Under conditions where oil was used with lower efficiency 14 gallons of 142,000 B.t.u. per gallon oil has been replaced by 1000 cubic feet of 600 B.t.u. manufactured gas. In other words, from 800,000 to 2,000,000 B.t.u.'s using oil as a fuel has been substituted by 600,000 B.t.u.'s using a manufactured gas with a high flame temperature as a fuel. A pound of coke has been replaced by 14 cubic feet of coke oven gas or 8400 B.t.u.'s of high flame temperature gas by 14,400 B.t.u.'s in coke. In comparing two gaseous fuels, one with a high flame temperature and one with a low flame temperature, it was found that 59 B.t.u.'s of coke oven gas has been made to do the work of 100 B.t.u.'s of producer gas. At Buffalo in the heating of wrought iron 36,900 cubic feet of producer gas was replaced by 6800 cubic feet of coke oven gas or with 4,000,000 B.t.u., of high flame temperature gas,

the same work was done as with 5,400,000 B.t.u's of a relatively low flame temperature gas such as producer gas.

At a large automobile plant on high temperature forging we have substituted 11 B.t.u.'s using coke oven gas or 10 B.t.u.'s using blue water gas for 15 B.t.u.'s using fuel oil. From this example it is seen that the possible efficiency of utilization of a fuel is directly proportional to its flame temperature and this fact coupled with the actual comparative operating results prove conclusively that the most efficient fuel is one having a high flame temperature, such as blue water gas.

Another factor of essential importance in the heat treatment of steel is the formation of scale or the oxidation of the metal. Flue gases of any fuel contain varying amounts of water vapor, carbon dioxide, carbon monoxide, and nitrogen. When the fuel is burned with an excess of air the flue gases contain an appreciable amount of oxygen. This oxygen unites with the steel forming the undesirable oxide or scale. To reduce the scale effect to a minimum, it is good practice to burn the fuel with a slightly insufficient amount of air so that the flue gases contain a small percentage of carbon monoxide and no oxygen. Under these conditions far better results have been obtained with a high flame temperature gaseous fuel than with fuel oil. At one of the largest automobile plants in the country some 200 tests were run during a period of several weeks to determine the relative values of fuel oil and blue water gas for high temperature forging. The results were decidedly in favor of the gas. On several weeks actual production the following results were obtained:

1. Increased production for gas over oil, 24.6 per cent.
2. Fuel saving of gas over oil on basis of oil, 27.4 per cent.
3. The gas furnace showed 36.6 per cent less scaling effect than the oil furnace.
4. The oil furnace had 800 per cent more burned forgings than the gas furnace.
5. Rejections were 50 per cent more on oil furnace forgings than on gas.

Because of the fact that the gas supply and air supply is so easily controlled almost any desired atmosphere is maintained in the furnace. Blue water gas undergoes combustion more readily and more quickly than any other fuel and therefore only the effect of the flue gases on the steel need be considered. For fuels which require slow combustion not only must the effect of the flue gases on the metal be considered but also the various constituents of the unburned fuel together with the nitrogen-oxygen mixture of the air. With such a fuel which undergoes slow combustion, it is often necessary to have a separate combustion chamber so that by the time the products of combustion reach the metal of the furnace, the unburned fuel has been consumed entirely and no unburned fuel or oxygen is left to come in contact with the metal. Therefore, as far as our knowledge goes at the present time, a gaseous fuel of high flame temperature and of a high rate of combustion is best adapted to heating operations.

Practice has reached the point where a slightly under-ventilated flame is used and the flue gases contain water vapor, carbon dioxide, carbon monoxide and nitrogen thus only small amounts of scale are found. Today this represents the best and most efficient practice. As far as is known nitrogen is inert and does not effect the metal. Carbon monoxide after prolonged heating will tend to effect decarbonization but when it is

present only in a small percentage, its effect is not detrimental. Water vapor reacts with the steel forming magnetic oxide of iron and hydrogen. It has been found that at the high temperature, the steel is readily oxidized by carbon dioxide forming iron oxide and carbon monoxide. In passing pure carbon dioxide over the metal at 2000 degrees Fahr., it was found that the metal was readily oxidized to the extent of 14.5 per cent and the final analysis of the gas showed only 70 per cent carbon dioxide and 30 per cent carbon monoxide. These results show conclusively that the metal is not only oxidized by the water vapor but is also effected by the carbon dioxide content of the flue gases. This problem is one of interest and further research and experimentation probably will show relative effects of all constituents of the flue gases on the metal.

The manufacture of a gas such as blue water gas is extremely flexible. It can be manufactured so that it will have a high carbon content and low hydrogen content if it is found that such a gas is preferable. If it is found that a gas with a high hydrogen content and a low carbon content is an ideal fuel for heat treatment a gas of this kind can be manufactured. In other words, whatever is found from research work, to be the ideal fuel for heat treatment within certain limits, such a gas can be manufactured and will perform with the least possible amount of scaling. In particular cases such as the making of a highly specialized product resource is always had to the muffle type furnace where the flue gases do not come in contact with the metal.

Summarizing, it is found that a consideration of the ideal fuel for the heat treatment of steel must be of the following nature: In the first place the fuel must be permanent so that all our future developments and furnace installations can be utilized for many years to the greatest possible extent. In the second place, the fuel must have a high efficiency of utilization. It must be a fuel that will heat the metal with absolute uniformity in the minimum amount of time. Then again the effect of the flue gases of the fuel or the oxidation of the metal is an important factor. It must be a fuel which can be so manufactured and utilized to give a minimum of scale and not to effect economic production seriously. Then again such a fuel as is best suited for industrial operations should be somewhat allied with the developments of all our fuel resources so that ultimately fuel manufacture can be standardized and produced at large central stations. This means enormous production, distribution and utilization, in other words, a cheap fuel. A fuel that approaches all the requirements of this ideal fuel is blue water gas. It is permanent; it has the highest efficiency of utilization and its manufacture can be varied so that it will cause less scale than any other fuel. Coupled with this fact is the tendency toward the development of a similar fuel by public utility gas companies. Oil for gas making is rapidly disappearing. The B.t.u. value of the gas is being steadily lowered by public service commission regulations and gas consisting of a mixture of coal gas and blue water gas is rapidly becoming the universal fuel. Ultimately a much lower B.t.u. gas will be adopted. Such a gas will be essentially a blue water gas and will be universally applied to all heating operations.

INDUSTRIAL SIGNIFICANCE OF STANDARDIZATION

STANDARDIZATION stabilizes production and employment, since it makes it safe for the manufacturer to accumulate stock during periods of slack orders, which he cannot safely do with an unstandardized product.

2. Reduces selling cost. This is generally overlooked. Possibilities of reduced costs are generally even greater in distribution than in production.

3. It enables buyer and seller to speak the same language, and makes it possible to compel competitive sellers to do likewise.

4. In thus putting tenders on an easily comparable basis, it promotes fairness in competition, both in domestic and in foreign trade.

5. It lowers unit costs to the public by making mass production possible, as has been so strikingly shown in the unification of incandescent lamps and automobiles.

6. By simplifying the carrying of stocks, it makes deliveries quicker and prices lower.

7. It decreases litigation and other factors tending to disorganize industry, the burden of which ultimately falls upon the public.

8. It eliminates indecision both in production and utilization,—a prolific cause of inefficiency and waste.

9. By concentrating on fewer lines, it enables more thought and energy to be put into designs, so that they will be more efficient and economical.

10. By bringing out the need of new facts in order to determine what is best, and to secure agreement on moot questions, it acts as a powerful stimulus to research and development,—and it is thus in decided contrast to crystalization resulting from fixity of mental attitude.

11. It is one of the principal means of getting the results of research and development into actual use in the industries.

12. It helps to eliminate practices which are merely the result of accident or tradition, and which impede development.

13. By concentration on essentials, and the consequent suppression of confusing elements intended merely for sales effect, it helps to base competition squarely upon efficiency in production and distribution and upon intrinsic merit of product.

14. Standardization is increasingly important for the maintenance and development of foreign trade. There is strategy in nationally recognized "American" specifications.

15. The efficiency of competing countries, increasing through national standardization programs, is liable to transfer competition from foreign markets to our own shores.

16. Joint effort in bringing about standardization within and between industries almost invariably leads to better understanding and to beneficial co-operation along other lines,—a step toward the integration of our industries.

From a bulletin issued by the American Engineering Standards Committee, 29 West Thirty-ninth street, New York.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest
to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

CARBONIZING IN FUSED SODIUM CARBONATE. By W. A. Jayme, *Forging & Heat Treating*, Vol. VII, Page 507.

The object of the experiments reported was to study the case carbonizing of steel in fused sodium carbonate when (a) the piece is simply immersed in the bath, (b) the steel acts as a cathode in the fused bath, (c) the steel acts as anode in the fused bath and (d) the steel is neutral the bath acting as an electrolyte. In case (a) no carburizing action was noted. In (b) a case of eutectoid composition was obtained. In (c) the erosion of the steel was too rapid for any satisfactory carbonizing action. In (d) the carburizing action was too slight to be of any practical importance. On the basis of the present experiment the results obtained do not indicate that the method would be of commercial importance.

EFFECT OF HEAT TREATMENT ON PHYSICAL PROPERTIES

URANIUM STEELS. By H. S. Foote, *Chemical & Metallurgical Engineering*, Vol. 25, Page 789.

Uranium in quantities under 2.0 per cent has little effect on the transition points. Increasing the uranium to 6.97 per cent produces an austenitic steel. The uranium occurs associated with the carbide. Photomicrographs of several grades of uranium steel are shown. Small amounts of uranium have a very marked influence in increasing the physical properties of steel. The following table gives a comparison with other steels:

Composition Per Cent	Elastic Limit Pounds per Square Inch	Tensile Strength	Elong. in 2 in. Per Cent	Reduction of Area Per Cent
Carbon 0.32, uranium 0.22	154,800	162,800	15.5	59.3
Carbon 0.30, nickel 3.5	111,000	124,000	15.5	53.3
Carbon 0.30, chromium 0.95, vanadium 0.18	146,200	162,700	15.0	57.0
Carbon 0.28, chromium 0.85, molybdenum 0.37	154,000	165,000	15.0	58.5

Uranium nickel steels show excellent properties and high speed steel is said to be benefited by the addition of uranium.

HARDNESS VARIATIONS IN HEAT TREATED STEEL. By C. R. Hayward, *Chemical & Metallurgical Engineering*, Vol. 25, Page 695 (1921).

It has been the author's experience that heat treated ¾-inch steel is generally harder in the center than at the edge. Several experiments on ¾-inch, 0.40-0.45 per cent carbon bar stock are cited. Differences of from 2 to 8 Shore hardness numbers were noted. An adequate explanation of this phenomena awaits further careful research.

HEAT TREATMENT IMPROVES STEEL CASTINGS. By M. M. Rock, *The Foundry*, Vol. XLIX, Page 797.

No standard practice is at present in existence for the annealing of steel castings. Tests were made to determine the efficiency of various heat treatments. Those studied were: (a) water quenching after four hours soaking at 1650 degrees Fahr. followed by drawing at 1220-1250 degrees Fahr.; (b) air cooling after four hours soaking at 1650 degrees Fahr. followed by drawing at 1220-1250 degrees Fahr.; and (c) annealing four hours at 1650 degrees Fahr. and furnace cooling.

Tensile tests showed little improvement in tensile properties due to the heat treatment. Tests made with the Russel, Izod and Charpy impact machines showed the heat treatment produced marked improvement. Tables of data are given.

THE "CHARACTERISTIC CURVES" OF THE HEAT TREATMENT OF STEELS. By A. M. Portevin and P. Chevenard. Read at the Paris meeting of the Iron and Steel Institute, *Engineering,* Vol. CXII, Page 551.

The results of heat treating steel are largely determined: (a) by the temperature to which the steel was heated and (b) the rate of cooling. By using these two variables as co-ordinates it is possible to draw curves showing the limits of annealing, and partial and maximum hardening conditions. These are the "characteristic curves." In order to obtain these curves it is necessary to determine accurately the "final state" of the steel. This is accomplished by dilatometric measurements during cooling and by the determination of Brinell hardness of the sample. Data has been established for several common industrial types of steel. Results are plotted for a steel of the following composition: carbon 0.50; manganese 0.30; nickel 2.65; and chromium 1.65 per cent. The above mentioned curves coupled with a knowledge of the cooling capacity of the quenching medium makes possible an accurate prediction of the influence of mass on the effects of heat treatment.

AN EXPERIMENTAL INVESTIGATION OF THE MECHANICAL PROPERTIES OF STEELS AT HIGH TEMPERATURES. By E. L. Dupuy, Iron and Steel Institute, Read at the September meeting in Paris.

The investigation covers steel running from 0.15 to 1.25 per cent carbon and a temperature range extending from room temperature to the melting point of the alloys. The breaking strength and reduction of area taken as characteristic of the physical properties. Both rolled and cast metals are used. The data is presented in the form of curves. In general the breaking strength curves show a maximum at 300-350 degrees Cent. from which the strength falls off to zero at the melting point. The reduction of area curves show a low point at 300-325 degrees Cent. and rise to 100 per cent between 1000 and 1250 degrees Cent. At the melting point the reduction of area curves also drop to zero.

STRUCTURAL PROPERTIES OF METALS AND ALLOYS. By R. W. Woodward, *American Machinist,* Vol. 55, Pages 596-599 and 636-638.

The author points out the necessity for understanding the possibilities and limitations of the various metals. The various physical properties, including thermal, magnetic and optical properties are taken up and tables of data are given for all of the common metals. No new data is submitted.

HEAT TREATING EQUIPMENT AND PRACTICE

COOLING OIL FROM QUENCHING TANKS. By S. E. Derby, *Forging & Heat Treating,* Vol. VII, Page 528.

An oil cooler is described and tables and curves are given showing the rate of heat transference from oil to water.

A NEW HEAT TREATING PLANT FOR MOTOR PARTS. By C. A. Armstrong, *Forging & Heat Treating,* Vol. VII, Page 515.

This is a description of the Milwaukee plant of the Nash Motors Co.

FEATURES OF ELECTRIC TOOL STEEL PRACTICE. By W. J. and S. S. Green, *Iron Age,* Vol. 108, Page 1061.

The authors recommend that tool steel manufacturers specialize as far as possible on ingot size. For carbon tool steel the larger the ingots the better. The melting shop should concentrate on production as far as possible and leave experimenting to other forces. The development of the electric furnace in the tool steel industry is followed and its products compared with the crucible process.

METALLOGRAPHY AND HARDNESS THEORY

A NEW ETCHING REAGENT FOR CHROME AND TUNGSTEN STEELS. By Karl Daeves, *Stahl and Eisen,* Vol. 41, Page 1262.

The use of an etching medium composed of potassium ferricyanide (20 gr.)

sodium hydroxide (10 gr.) and water (100 gr.) is described. Its use is restricted to high chrome and to high speed steel, ordinary low chrome structural steels not being etched.

THE MICROSCOPIC STUDY OF THE STRUCTURE OF METALS. By H. S. Rawdon, *American Machinist,* Vol. 55, Page 659.

The value of metallographic inspection in testing materials is developed. The use of the microscope is described and a large number of characteristic photomicrographs shown.

MIXED ORIENTATION DEVELOPED IN CRYSTALS OF DUCTILE METALS BY PLASTIC DEFORMATION. By E. C. Bain and Zay Jeffries, *Chemical & Metallurgical Engineering,* Vol. 25, Page 775.

From X-ray spectrographs the effects of cold work are elucidated.

THE AMORPHOUS METAL HYPOTHESIS. By Zay Jeffries and R. S. Archer, *Chemical & Metallurgical Engineering,* Vol. 25, Page 697.

The amorphous cement hypothesis and its applications to plastic deformation are explained.

STRENTHENING METALS BY COLD-WORK. *Chemical & Metallurgical Engineering,* Vol. 25, Page 697.

An exposition of Prof. E. Heyn's views on the hardening theory is given.

SOME UNUSUAL STEELS

DAMASCENE STEEL AND ITS ORIGIN. By Col. N. T. Belaiew, *Blast Furnace and Steel Plant,* Vol. 9, Page 621.

Damascene steels are hyper eutectoid carbon steels containing about 1.5 per cent. Through a careful forging process the cementite is thoroughly spheroidized. The microstructure is very similar to high speed steel and similarities in treatment are pointed out.

NON-MAGNETIC, ACID AND RUST-RESISTING STEEL. *Chemical & Metallurgical Engineering,* Vol. 25, Page 797.

The properties of a steel called "Resistal," developed in the research laboratory of the Crucible Steel Co. of America, Pittsburgh, giving its physical and acid resisting properties, are described.

TESTING INSTRUMENTS

INSTRUMENT TO MEASURE ELONGATION OF BROKEN TENSILE SPECIMENS. By R. W. Woodward, *Chemical & Metallurgical Engineering,* Vol. 25, Page 756.

An instrument is described which is direct reading. The bars are held by center points and per cent elongation in two inches is read from a dial attached to one of the index points.

THE USE OF THE SCLEROSCOPE ON LIGHT SPECIMENS OF METALS. By F. S. Tritton, *Engineering,* Vol. CXII, Page 492.

Samples of metal weighing considerably less than a pound do not give the same reading on the scleroscope as samples of identical properties weighing over a pound. Clamping in a vice does not improve the practice. The readings are from 80 to 35 points low for the light pieces of metal. By mounting the light specimens on pitch in a clamp designed by Rosenhain the readings may be made to check. Mounting the specimens on steel blocks weighing a pound by means of glucose also gave satisfactory results.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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SHIRAI & CO. INC., (Sb.-11), 291 Broadway, New York City.
TYMES, H. W., (M-11), 1466 Broadway, Watervliet, N. Y.

CHANGES OF ADDRESS

ANGER, EARL M.—from Liberty Steel Corp., Box 12, Morristown, N. J., to Crystal, Conn.
ARMET, LESLIE R., MGR.—from 815 Hickory St. to 3732 Bamberger Ave., St. Louis, Mo.
BALDWIN, JAS. P., (M-1)—from 66 Forest St. to 272 Corbin Ave., New Britain, Conn.
BEAUMONT, J. S., MET.—from P. O. Box 724 to P. O. Box 501, Walkerville, Ont., Canada.
BELLIS, C. B., (M-8)—from 173 West Rock Ave. to 335 Winthrop Ave., New Haven, Conn.
BLISS, I. R.—from Atlas Crucible Steel, 3567 Lindell Blvd. to 3850 Westminster Ave., St. Louis, Mo.
BOURRASSA, A. A.—from 2428 Tremont Ave. to 2134 Farnam St., Davenport, Iowa.
BOYER, SHERMAN H.—from 311 Hubbard Ave. to 1065 Hubbard Ave., Detroit, Mich.
BULL, IRVING C.—from Bull & Roberts, 100 Maiden Lane to 50 West St., New York City.
CANNON, J. D.—from 622½ Fifth Ave., Milwaukee, Wis., to 129 2nd St., New Castle, Del.
CASSELMAN, F. J., SUPT.—from The John Steptoe Co., 2951 Colerain Ave., to 3206 Colerain Ave., Oakley, Cincinnati, Ohio.
GALLAHER, RAY C.—from 50 Huffman Ave., to 1004 Haynes, Dayton, Ohio.
GEISSINGER, H. G. (A-4)—from H. L. W. Mfg. Co., 20th & Fort to 411 Kresge Bldg., Detroit, Mich.
GILGER, GEORGE A. JR.—from 207 Catherine St. to 360 Cortland Ave., Syracuse, N. Y.
GRENON, JOSEPH A., (M-12)—from 12 Leversque Ave., Hartford, Conn., to 45 Lakeside Ave., Marlboro, Mass.
HARDY, CHAS.—from 50 Church St., to 115 Broad St., N. Y.
HARR, DAVID P.—from Hotel Stevenson, 46 Davenport, to 1350 E. Jefferson Ave., Detroit, Mich.

HARRIS, S. A., MET.—from Jas. H. Herron Co. to 2079 E. 46th St., Cleveland, O.
HOBBS, ALFRED, (M-11)—from 529 Delaware St. to 300 Parkway Dr., Syracuse, N. Y.
HOUSER, GEO. B., (M-10)—from 416 Renwich Ave. to 317 Burt St., Syracuse, N. Y.
HOYT, SAMUEL L.—from Nela Park, Cleveland, to Brown Ave., Willoughby, Ohio.
JOHNSON, S. S.—from Pelton Steel Co. to Milwaukee Steel Foundry, Milwaukee, Wis.
KERNOT, A. H., (M-3)—from 103 Marquette Ave. to 829 Van Buren, South Bend, Ind.
KIMMEL, GEO. C.—from The Cincinnati Grinder Co., 3233 Colerain Ave., Cincinnati, Ohio to Murbury & South Aves., Oakley, Cincinnati, Ohio.
KRUGER, LOUIS P.—from Angsten Kox Co. to P. O. Box 256, Michigan City, Ind.
LARDNER, JAS. F. JR.—from Y. M. C. A. to John Deere Plow Wks., Moline, Ill.
MACKENZIE, WM. J.—from 5227 Woodlawn Ave. to 5338 Blackstone, Ave., Chicago, Ill.
MILLER, JOSEPH J.—from 601 Bailey Farrel Bldg., Pittsburgh Pa. to Gulic, Henderson Co., Inc., 525-529 3rd St., Pittsburgh, Pa.
NEWBOLD, L. T.—from 1853 Newton St., N.W., Washington, D. C. to University of Cincinnati, 140 W. University Ave., Cincinnati, Ohio.
POLHEMUS, G. JULES—from 1238 40th St., West Washington Blvd. to Ludlum Steel Co., Peoples Gas Bldg., Chicago, Ill.
PUTNAM, A. H.—from P. O. Box 653 to 1710 E. 12th St., Davenport, Iowa.
RAWSON, ROLLIN—from 2280 E. 93rd St. to 2163 E. 87th St., Cleveland, O.
REYNOLDS, C. M.—from 311 Main St. to 475 Shrewsburg St., Worcester, Mass.
RUDDELL, ROBERT J.—from 311 Hubbard Ave. to 1065 Hubbard Ave., Detroit, Mich.
SCHNEID, R. A., (M-12)—from 569 Bryant Ave. to 263 Tennyson Ave., Syracuse, N. Y.
TARBOX, GURDON, (M-9)—from Spicer Mfg. Co. to 425 E. 7th St., Plainfield, N. J.
THOMSON, W. G. H. (M-10)—from 1455 W. 37th St. to P. O. Box 263, Rockford, Ill.
TIFFNEY, GEORGE E., (M-11)—from Colts Patent Fire Arms Co. to 683 New Britain Ave., Hartford, Conn.
TOUR, SAM—from 1340 Gillatin N. W., Washington, D. C. to 2225 Ditmas Ave., Brooklyn, N. Y.

MAIL RETURNED

BASTION, WM., 709 Avery Ave., Syracuse, N. Y.
KMAN, GEORGE, (M-4), 855 W. 51st Pl., Chicago, Ill.
LANFER, EMIL, 315½ Genesee St., Syracuse, N. Y.
WOLFE, H. S., (M-3), 726 Pembroke Rd., Bethlehem, Pa.

News of the Chapters

ELECTED DEAN OF SCHOOL OF FOREMANSHIP

THE *Rocky Mountain News* of Denver contains a write-up and photograph of T. E. Barker, formerly first vice president of the American Society for Steel Treating, as follows:

"T. E. Barker, general superintendent of the Denver Rock Drill Company, has been elected dean of the new school of foremanship which is to be organized at the Y. M. C. A. next Wednesday evening. A committee of personnel managers and superintendents of a number of the leading shops of the city is co-operating with the Y. M. C. A. schools in putting on this course.

"While this course is intended largely for foremen and assistant foremen in establishments having production departments, it also is intended that it shall be of service to men in any industry in which a study of personnel problems will be of advantage. This course will cover a period of four months.

"Dean Barker will select a number of experts in this field here in Denver to assist him in giving instruction. It is expected that a number of industries will assist their foremen and assistant foremen to attend this course by paying a part of the tuition."

PROVIDENCE CHAPTER

The November meeting was addressed by Victor E. Hillman, metallurgist for Crompton & Knowles Loom Works, Worcester, Mass. His subject "The Efficiency of Different Mixtures for Cyanide Hardening, and the Role of Nitrogen in the Process", was illustrated by lantern slides. The meeting was of special interest from a practical point of view, was quite well attended, and proved to be very interesting.

CLEVELAND CHAPTER

President F. P. Gilligan paid his first official visit to this chapter on Thursday evening, Oct. 28, when over 100 members and friends met at the Engineering Society's rooms at the Winton Hotel. President Gilligan presented a talk on "Alibis for the Hardening Room" which proved to be very acceptable. The address was well illustrated.

In addition to President Gilligan, a number of other National Officers were present, having arrived in Cleveland to attend the meeting of the Board of Directors on Oct. 29.

PHILADELPHIA CHAPTER

Over 100 attended the regular meeting of the Philadelphia Chapter held at the Engineers' Club on Oct. 28. T. Holland Nelson presented a very interesting paper on the subject of "Comparison of English and American Methods of Manufacture of Crucible Steel." The paper was profusely illustrated and as the subject indicates, gave a comparison on the different methods of manufacture.

TRI CITY CHAPTER

The Tri City Chapter has prepared a special announcement of a series of practical and technical talks to be given on the Thursday following the first Monday of each month. These talks will be presented by men of national prominence who have made their subjects a specialty, and who are thoroughly capable of presenting them in a manner which will be readily understood.

SPRINGFIELD CHAPTER

Quite a large number of members gathered at the Chamber of Commerce on Nov. 18 to hear H. J. N. Voltman, of the W. S. Rockwell Co., New York City, present an interesting illustrated lecture on "Equipping and Laying-Out the Heat Treating Department of a Small Industrial Plant". Mr. Voltman is an authority on the subject of heat treating equipment and his talk was of the same high standard he has maintained in the many excellent publications issued by this firm.

Arrangements were also made for visitation to the Rolls-Royce automobile plant.

BOSTON CHAPTER

A. H. d'Arcambal, chief metallurgist of the Pratt & Whitney Co., Hartford, presented an illustrated paper on "High Speed Steel" before the Boston Chapter in Room 1 of the Boston City Club on Nov. 18. Mr. d'Arcambal is an authority on high speed steel. The discussion following the presentation of his paper was very heartily entered into by the large number present. While Mr. d'Arcambal was in Boston, he addressed the mechanical engineers of the Massachusetts Institute of Technology.

NEW YORK CHAPTER

The New York Chapter has made arrangements for the use of a lecture room at the Engineering Societies Building, and its meetings in the future will be held there. The Program Committee consisting of Mr. Graham, Chairman, and Mr. Thum and Mr. Fishback, members, has planned a very interested series of meetings for the year.

On Nov. 16, T. H. Nelson, works manager of H. Disston & Sons, Philadelphia, presented a very interesting paper of the manufacture of tool steel. Dr. Federico Giolitti, the eminent Italian metallurgist and international authority on case hardening, was a guest of honor at this meeting.

The practical talks for the 1921-22 season are as follows:

DECEMBER:—What happens to steel when you heat and quench it.

JANUARY:—Annealing and tempering machine and tool steels.

FEBRUARY:—Case hardening (carburizing and subsequent heat treatment). Ways of doing it, and what it does to a piece of steel.

MARCH:—Treatment of high speed steel.

APRIL:—Hardening room troubles, shrinkage, warpage and scaling.

MAY:—Up-to-date hardening room equipment, furnaces, pyrometers and auxiliaries.

JUNE:—Spotting the reason for failures in service. Practical uses for microscopes and physical testing machines.

Added Attraction:—Current events, a 10-minute talk at each meeting on recently published items of interest to heat treaters. Come to the meetings and get into the discussions of the topic presented.

HARTFORD CHAPTER

The Hartford Chapter held its November meeting in Jewell Hall, Y. M. C. A. on Nov. 10. A paper on "Case Hardening" was presented by Stanley P. Rockwell, consulting metallurgist. Mr. Rockwell handled his subject in a very capable manner due to his wide experience acquired while in the employ of firms doing carburizing on a large scale. Mr. Rockwell described the advantages and disadvantages of the various treatments and materials used in commercial operations. About 120 were present, and there was considerable discussion.

R. K. Newman, of the Frasse Steel Co., Hartford, Conn., described a recent application of a chrome-tungsten steel to a difficult die job, as well as telling of the "Jones" test which was used to guide in the selection of the proper heat treatment.

The December meeting will be held on Thursday, Dec. 8, at Jewell Hall. The paper "Spring Manufacture" will be presented by George P. Moore who directs the metallurgical work at the Wallace Barnes Co., of Bristol. Many of the methods of this industry were originated by this company and they still maintain an active leadership in the development of new and up-to-date processes.

ST. LOUIS CHAPTER

Due to the illness of Mr. Maher, Chairman of the St. Louis Chapter, his resignation was presented and accepted with regret. Fred Key, manager of the St. Louis Pressed Steel Co., 27th and McCausland avenues, E. St. Louis, Ill., was selected as chairman of the Chapter.

The November meeting was held on Nov. 10 at the Engineers' Club room. W. S. Bretschneider, of the Norton Company, spoke on the "Selection of Grinding Wheels for the Tool Room." As a special feature, Charles LeCompte gave a chalk talk. The meeting was very well attended and proved to be most interesting.

DETROIT CHAPTER

C. H. Heilman gave an interesting talk on "Correlation Between Testing of Materials and Service" to 125 members and friends of the Detroit Chapter who gathered at the Board of Commerce rooms. The discussion was excellent and was entered into with great enthusiasm by the men present.

CHICAGO CHAPTER

A practical discussion of shop problems was entered into by 120 members who gathered at the City Club on Nov. 10. These meetings have always been decidedly popular with the Chicago membership, and many questions were presented and discussed at this meeting.

ROCHESTER CHAPTER

The Rochester Chapter held its November meeting in the Engineering Society Club rooms on Wednesday, Nov. 9. Robert Smith, of E. F. Houghton & Co., presented a paper on "Quenching Mediums" and Lloyd K. Marshall, chairman of the Chapter, presented his paper on "Tool Steel Manipulation", that he prepared and presented at the Indianapolis Convention. Both papers were of much interest and caused a large amount of discussion.

SYRACUSE CHAPTER

About 100 members gathered in the ball room of the Yates Hotel to attend the November meeting of the Syracuse Chapter. George M. Berry, chief chemist of the Halcomb Steel Co., presented an interesting talk illustrated with lantern slides on the subject, "From Ore to Steel". Mr. Berry presented his paper in an excellent manner, and the meeting proved to be a very enjoyable one. A buffet luncheon was served at the close of the meeting, which assisted in adding to the enjoyment of the occasion.

SCHENECTADY CHAPTER

The November meeting of the Schenectady Chapter was addressed by T. S. Fuller, metallurgist of General Electric Co., on the subject, "Corrosion of Iron and Steel". The rust problem is one in which all the members were interested, and Mr. Fuller's collection and presentation of the material on this subject as well as his own special study of corrosion combined to make the evening a very profitable one.

Entertainment features were furnished by A. Decrenzo, pianist, and W. Melber, baritone, gave several selections. An orchestra was also in attendance, and gave a number of selections.

WORCESTER CHAPTER

The Worcester Chapter has adopted the policy of mimeographing the discussions held upon the papers presented at their meetings. The first of these mimeographed discussions was upon the paper presented by Wheaton B. Byers, on the subject of "Carburizing". Three very interesting pages of discussion were collected at this meeting, and mailed to the membership.

SOUTH BEND CHAPTER

The October meeting of the South Bend Chapter was held Oct. 13 at the Y. M. C. A. The "Studebaker Industrial Films" were shown and this was followed by a talk by Mr. Freydendahl, of the Chicago Flexible Shaft Co., on the "Principles of Combustion", as applied to furnaces. About 60 attended the meeting.

Mr. W. R. Newhouse has been appointed chairman of the organization committee.

The Chapter held its regular meeting on Nov. 8 at the Y. M. C. A. building. In spite of the meeting falling on election night and in spite of a violent combination rain, hail and snow storm, 55 members and guests attended the meeting. Due to the fact that the Chapter has a number of foundrymen as members and also to the fact that there are a large number of foundries located in that territory, the usual program was departed from by securing as speaker for the evening, Clement A. Hardy, of the Clement A. Hardy Co., of Chicago, engineers of design and operation of foundries and allied industries. Mr. Hardy chose as his subject, "Common Sense Foundry Engineering". He first discussed the points to be taken into consideration in building a foundry and followed up by a series of slides of the new foundry of the Fairbanks, Morse Co., at Beloit, Wis. This is a foundry designed to produce 500

tons of castings per day. His paper was followed by a discussion which dealt with everything from building material to analysis of iron used in the different types of castings.

It was the opinion of most of those attending the meeting that it was one of the most successful meetings ever held. As the success of the Chapter depends on getting the shopmen interested it will be necessary to follow this up with practical talks on the various methods of manufacture of steel and its products.

WASHINGTON CHAPTER

Owing to changes in business connections of several members of the Washington Chapter there have been changes in the personnel of committees and in Chapter officers as follows: Chairman, H. J. French, division of metallurgy, Bureau of Standards, Washington, D. C.; Vice Chairman, W. L. Blankenship, U. S. Navy Yard, Washington, D. C.; Secretary-Treasurer, J. Straus, U. S. Navy Yard, Washington, D. C.; and Chairman of Meetings Committee, J. S. Vanick.

Mr. Tour, former chairman of the Chapter has gone to Brooklyn, N. Y., and H. E. Handy, former chairman of the Meetings Committee, expects to leave Washington in the near future. Both men expressed regret at leaving the local section and only resigned their respective connections with the Chapter because of removal from the city.

The next meeting will be held on Nov. 18 and meetings will hereafter take place on the second Friday of each month. At the next meeting a motion picture will be shown depicting the manufacture of American ingot iron and a short paper will be presented by J. S. Vanick on "Nitrides in Steels".

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held the second meeting of its series on "The Manufacture, Treating and Testing of Steel" at the Battery Building of the Bethlehem Steel Co., Nov. 7. The feature of the meeting was an illustrated talk given by B. H. DeLong, metallurgist of the Carpenter Steel Co., Reading, Pa., on "The Manufacture of Tool Steel".

Mr. DeLong portrayed with slides and explained in detail every operation employed in the manufacture of high-grade tool steels. Beginning his lecture, Mr. DeLong gave a brief history of iron and steel and stated that iron was known to have been used 3500 years B. C. and that steel saws which had been tempered were found underneath the pyramids, these having been made 800 years B. C. Describing the processes employed in the making of weapons of warfare down through the ages, Mr. DeLong said that even the Damascan swords could in no way be compared to the quality of high-grade steels manufactured today.

In discussing the electric furnace and open-hearth processes of melting steel as compared with the crucible process, the speaker pointed out that for quality steel the crucible process was to be preferred. The practice of pouring the steel directly from the crucibles into the ingot moulds was discussed also and Mr. DeLong explained that the method employed by the Carpenter Steel Co. of pouring from the crucible into a large ladle and then pouring the ingots from the ladles produced a cleaner and uniformly better steel.

Throughout his entire talk Mr. DeLong emphasized the importance of the human element and how necessary skilled and competent workmen were to the production of high-grade tool steel. Mr. DeLong proved

to be a speaker of exceptional ability. He was thoroughly acquainted with every phase of his subject and delivered it in a manner which made it very highly interesting as well as instructive.

Before and after the lecture the members took advantage of and were much interested in the Bethlehem Steel Co.'s exhibit at the Battery Building and it was at a late hour when the meeting adjourned. It was announced at the meeting that Frank P. Gilligan, newly elected President of the National Society, would be with the local Chapter at its next meeting to be held Nov. 28.

NORTH WEST CHAPTER

The following item of interest has been taken from the *Weekly Bulletin* published by the Manufacturers' Club of Minneapolis:

The first lecture in the Educational Course on Steel Treating will be held Monday evening, Oct. 24, at 8:00 o'clock, at the Club rooms, Chairman O. E. Harder, Professor of metallography at the University of Minnesota, will present the subject of "Composition, Elements and Classification of Steels, together with their meaning," which will be illustrated by lantern slides. The lecture will consume about an hour and will be followed by a general discussion led by members of the Executive Committee.

These educational lectures, nine in all, will be held on the fourth Monday of each month, and will cover in a nontechnical way the fundamentals of metallurgy and steel treating. They will be of exceptional interest to every one engaged in the iron and steel line.

H. K. Briggs, Minneapolis Electric Steel Castings Co., Chairman of the Educational Committee, is very much gratified at the way member concerns of The Manufacturers' Club are supporting this course. Already 73 men have been enrolled, none of whom are members of the Steel Treaters' Section. The Woolery Machine Co. will undoubtedly have the largest representation as H. E. Woolery has enrolled 12 of his men for the entire course. He says he is willing to gamble a dollar that each of them will receive manifold returns.

Chester S. Moody, Minneapolis Steel & Machinery Co., Chairman of the Meetings and Papers Committee, has announced the following program for the first meeting in each month:

November—Mr. Belleville, vice president, Commonwealth Steel Co.
Subject: "For the Good of the Commonwealth, or The Inside of the Electric Furnace." Three reels of motion pictures.

December—Mr. Farquhar, metallurgist, Electric Steel Co. of Indiana.
Subject: "Electric Steel."

January—C. S. Spaulding, metallurgist, Halcomb Steel Co., Syracuse, N. Y.
Subject: "A Comparison of the Rate of Penetration of Carbon in the Various Commercial Steels in Use for Case Carburizing." Illustrated.

February—A. H. D'Arcambal, metallurgist, Pratt & Whitney, Hartford, Conn.
Subject: "Physical Tests on High Speed Steel." Illustrated.

March—H. A. Schwartz, director research, National Malleable Castings Co.
Subject: "American Malleable Iron."

April—C. P. Richter, Central Steel Co., Massillon, Ohio.
Subject: "Steel for Gears."

May—O. T. Muehlmeyer, metallurgist, Barber-Coleman Co., Rockford, Ill.
Subject: "Steel Dies."

June—To be arranged. Probably a picnic.

The foregoing program has been arranged in conjunction with other chapters of the American Society for Steel Treating. Exact dates of the meetings will be announced as soon as they are fixed.

Another write-up in the same publication was as follows:

"The first lecture in the educational course conducted by this Section was held Monday evening Oct. 24th, in the Club rooms. Approximately 125 were present, including members and those enrolled for the course which was most gratifying to the committee in charge.

Chairman O. E. Harder discussed the "Composition and Classifications of Steels and Their Meanings," which was illustrated by lantern slides. An 11-page

brief, summarizing the lecture, has been prepared for distribution. Copies may be obtained without expense by any one who is interested, upon application at this office.

Mr. Harder in his introduction, as showing the range and variety of the subjects to be handled in this course, said:

The subject-matter to be given in this series of lectures will include a somewhat broader field than that usually referred to as steel; for example, it will include cast iron, malleable cast iron, semisteel, and wrought iron, as well as various kinds of straight carbon and alloy steels. It will be the purpose of this first lecture to outline in a general way, and show by a diagrammatic summary, the various steps in the production of the materials mentioned above from the iron ore. The blue print included in the notes covering this lecture will make it possible to follow the various steps in the production of many types of finished products. They will be taken up in the following order: Cast iron, malleable cast iron, semisteel, wrought iron, cast steel, and steel. The latter term covers plain carbon steels, alloy steels, and high speed tool steels. Strictly speaking, these kinds of steels should be called wrought steel as a distinction from cast steel.

Ninety-seven men employed by member concerns have been enrolled in this course. The entire expense is but $1.00. Enrollments are still being accepted. The subjects covered include metallurgy as well as steel treating, and will be of exceptional value to those in the metal products line. If there is any one in your organization who may be interested, send his name to this office, and he will be placed upon the enrollment list. He will also be privileged to attend the regular meeting of the Section held monthly, at which more technical subjects are discussed."

The regular meeting of the members of the Northwest Chapter was held Wednesday evening, Nov. 16, at The Manufacturers' Club, 200 Builders Exchange. Francis B. Foley, metallurgist for the United States Bureau of Mines, stationed at the Minnesota Section at the University of Minnesota, spoke on "Pyrometers."

Mr. Foley has had extensive experience in the field of pyrometry. He was engaged in research work for the Midvale Steel & Ordnance Co., of Philadelphia, from 1909 to 1917. From 1913 to 1917, he had charge of all the pyrometers in that important steel and ordnance plant. Since 1917 he has been engaged in a number of important investigations on war problems, researches for the National Research Council and for the U. S. Bureau of Mines. One of the important parts of his lecture was a thorough and comprehensive explanation of the principles of different classes of pyrometers.

Dinner was served as usual at 6:30, the business meeting commenced at 7:30.

Commercial Items of Interest

A BULLETIN issued by the American Engineering Standards Committee, 29 West Thirty-ninth street, New York, discusses industrial standardization work in Germany and emphasizes the point that insufficient attention has been given to the role which standardization is playing in German industrial reconstruction. Following are a few of the statements made in the report:

"The German industries are planning and are carrying out a far-reaching program of standardization as a necessary step in building up an unprecedented industrial structure which must rest in large measure on an extensive foreign trade. In no other country except Great Britain is standardization work being carried on upon a scale, or with an intensity, comparable to that in Germany. * * * It is remarkable that the national standardization movement in Germany should have been so thoroughly organized and that so much work should have been accomplished in four years. 144 approved standards sheets have been issued and over 500 others have been so far developed that they have been published in tentative form. * * * The standardization movement in Germany is particularly significant, since Germany is one of the three leading industrial countries. The industries of Austria, Holland, Sweden, and Switzerland, are so intimately related to those of Germany on account of geographical and other relationships, that they are necessarily affected very largely by developments in Germany. It appears that the work is being woven very intimately into the industrial fabric. The very large number of standards purchased by the industry, and the fact that the central organization has 5000 firms which are co-operating members, are a sufficient indication of this. There seems to be a striking analogy between the present standardization movement in Germany, and the research movement developed there a generation ago. Whatever estimate one may place upon the role it played in German industries generally, everyone agrees that research was fundamental in the development of their great chemical industries. The role which the Germans are expecting standardization to play in all their industries would be not unlike the role which research has played in their chemical work."

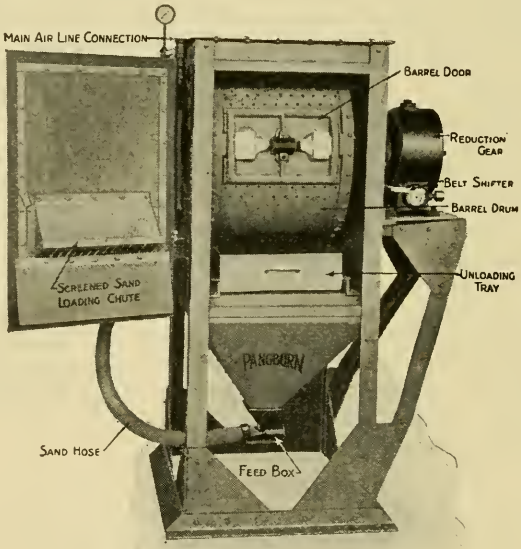
For the heat treating of small products, a new automatic, semicylindrical electric furnace has been developed by the General Electric Co., Schenectady, N. Y., which embodies several features contributing to the flexibility of temperature control. The equipment consists of the furnace, transformer automatic control panel, and a temperature control instrument mounted on the sub-base of the panel. The furnace consists of a sheet metal casing supported on legs and is lined with insulating material to form a semicylindrical chamber.

A continuous strip of resister ribbon shaped into an arch or succession of semicircular turns conforming to the arch of the furnace chamber and extending the whole length of the latter forms the heating element. Insulators between the turns provide a strong self-supporting winding flexible to expansion and contraction. The power cables are

attached to the back of the chamber. Heat is radiated direct to the charge, no muffle being used. By removing the front of the furnace and disconnecting the terminals at the back, the resistor may be pulled out bodily for inspection and repair.

Four coils form the primary of the transformer and may be connected in multiple, multiple series, or series for 110, 220 or 440 volts at 60 cycles. The secondary has two taps, one 70-volt giving 10 kilowatts for rapid heating and the other 50-volt giving 5 kilowatts for normal heating. The normal rating of the transformer is 7.5 kilowatts but 10 kilowatts may be obtained for short periods. The temperature control instrument has a scale range of 1000-2000 degrees Fahr. thus the furnace is protected from excess temperature. A special fuse melting at 1800 degrees Fahr. provides additional protection to the equipment.

For cleaning small heat treated pieces, the Pangborn Corp., Hagerstown, Md., has developed a small self-contained sand blast barrel. This device consists of a sheet metal, dust tight cabinet or housing on a structural steel frame, the bottom being hopper shape to receive the abrasive and equipped with a feed box to which is attached a hose that conveys the sand to the nozzle. The barrel drum, mounted within this cabinet or housing, is 24 inches diameter and 16 inches long and is con-



SAND BLAST BARREL FOR HEAT TREATED PARTS

structed of perforated sheet metal. It is revolved by gears connected to the main shaft. An opening at the other end receives the nozzle which is mounted on a swinging bracket to give easy access. Dust tight doors close the barrel housing and opening for the nozzle. Baffles inside the barrel drum turn the load as it rotates slowly, bringing all

pieces and faces under the blast action. The spent abrasive drops through the perforations of the drum into a screen tote box and through into the hopper for re-use. The equipment occupies a floor space of 2 feet 7 inches by 8 feet 6 inches and stands 5 feet 6 inches high.

Bulletin No. 240, issued recently by the W. S. Rockwell Co., 50 Church street, New York, and entitled "The Heat Treatment of Springs With Stationary and Continuous Furnaces," is an outline of the fundamental principles of heating and handling springs. It consists of eight pages and is made complete with illustrations showing cross sectional views of the various types of furnaces as well as practical installations. Much of the difficulty in the manufacture of springs is due to improper methods in the heat treating operations and the use of equipment and fuel not properly adapted to the manufacturing conditions. The purpose of the bulletin is to give information as to the application of principles which must be considered in improving the quality and decreasing the cost of springs and similar heat treated products.

According to an announcement appearing in the November issue of the Bulletin of the American Foundrymen's Association, the next convention and exhibit of the association will be held in Cleveland during the week of April 24, 1922. Headquarters and the exhibits will be in the new Cleveland Public Hall, at Lakeside avenue and East Ninth street, which is rapidly nearing completion. The Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers will hold its convention jointly with the foundrymen as has been the custom in past years. Of the cities considered, Cleveland is most centrally located for the membership, for the foundry industry, and for the manufacturers of foundry equipment and supplies who make annual exhibits, and its selection will conserve traveling and freight expense.

The powdered coal department of the Quigley Furnace Specialties Co., Inc., 26 Cortlandt street, New York, has been acquired by the Hardinge Co., 120 Broadway, New York. The latter company states no change will be made in the method of conducting the business at its offices, as the organization of the engineering department has been taken over practically intact. The transfer will not affect the refractory specialties business of the Quigley company, which includes the manufacture and sale of high temperature cement, insulating brick and other products. The rapid growth of this branch of business made it necessary that the company devote its entire attention to furnace specialties, with particular reference to refractory linings and the heat insulation of furnace structures.

A sales office has been opened at 134 South LaSalle street, Chicago, by the Interstate Drop Forge Co., Milwaukee, with Robert L. Peoples in charge.

Representation of the Ludlum Steel Co., Watervliet, N. Y., manufacturer of tool and special steels, in Wisconsin and Minnesota, has been taken by the Barber Iron & Steel Co., 329 West Water street, Milwaukee.

Stanley P. Rockwell, metallurgical engineer, 65 Highland street, Hartford, Conn., recently has announced his entrance into the consult-

(*Continued on Page* 34)

COMPARATIVE BRANDS OF

Compiled by Tool

COMPANIES	ADDRESSES	CRUCIBLE ANALYSIS TOOL STEEL
1. Atlas Crucible Steel Co.	1. Dunkirk, N. Y.	1. Atlas Common
2. Bethlehem Steel Company	2. Bethlehem, Pa.	2. Bethlehem X
3. Braeburn Steel Company	3. Braeburn, Pa.	3. Braeburn B T
4. Carpenter Steel Company	4. Reading, Pa.	4. Titan
5. Century Steel Co. of America	5. Poughkeepsie, N. Y.	5. Crucible Analysis
6. Colonial Steel Company	6. Pittsburgh, Pa.	6. Anchor
7. Columbia Tool Steel Company	7. Chicago Heights, Ill.	
8. Crucible Steel Co. of America	8. Pittsburgh, Pa.	8. Corona
9. Cyclops Steel Company	9. Titusville, Pa.	
10. Henry Disston & Sons, Inc.	10. Philadelphia, Pa.	10. Standard
11. Firth-Sterling Steel Company	11. McKeesport, Pa.	
12. Halcomb Steel Company	12. Syracuse, N. Y.	
13. Heller Brothers Company	13. Newark, N. J.	
14. Hess Steel Corporation	14. Baltimore, Md.	14. Hess Standard
15. Internat. High Speed Steel Co.	15. Rockaway, N. J.	15. Standard Tool
16. William Jessop & Sons, Inc.	16. New York, N. Y.	
17. Latrobe Electric Steel Co.	17. Latrobe, Pa.	
18. Ludlum Steel Company	18. Watervliet, N. Y.	18. Ludlum Carbon
19. Midvale Steel & Ordnance Co.	19. Philadelphia, Pa.	19. Mining Drill
20. Simonds Mfg. Company	20. Fitchburg, Mass.	20. Simonds No. 4
21. Vanadium Alloys Steel Co.	21. Latrobe, Pa.	21. Crucible Analysis
22. Vulcan Crucible Steel Co.	22. Aliquippa, Pa.	

SPECIAL TOOL STEEL	OIL HARDENING STEEL	ONE TO TWO PERCENT TUNGSTEN (INTRA) STEEL
1. Atlas XX	1. Deward	
2. Bethlehem XXX Special	2. Bethlehem Tool Room	
3. Braeburn Special	3. Braeburn Non-Shrinking	
4. Special	4. Stantor	4. K W
5. Red Label No. 42	5. Centaur No. 36	5. Wit-Edge No. 25
6. Colonial Special No. 14	6. Colonial Oil Hardening No. 6	6. Colonial Standard No. 5
7. Columbia Special	7. Columbia Oildie	
8. Atha Special Park Special Crescent Special Labelle Special Sanderson Special Howe-Brown Special Singer Special	8. Atha Non-Shrinkable Paragon	8. Champion Extra Viking Extra
9. Cyclops Special Tool	9. Cyclops Wando	9. Cyclops Para Steel
10. Special	10. Mansil	
11. Firth's Best	11. Firth-Sterling Invaro	11. Firth-Sterling Special Alloy
12. Special	12. Ketos	12. Liberty
13. Yellow Label		
14. Hess Special		
15. Double Special Tool		
16. Jessop's Best Cast Steel		
17. Special	17. Mangano	
18. Pompton Special	18. Oneida	18. Utica
19. W C S Extra	19. Constant	19. Alpha
20. Mecis		
21. Vasco Special	21. Vasco Non-Shrinkable Vasco Choice	21. Vasco Valutap
22. Special	22. Non-Shrinkable	22. Special W

AMERICAN TOOL STEELS

Steel Society, 1920

REGULAR TOOL STEEL	TWIST DRILL STEEL	EXTRA TOOL STEEL
1. Atlas Refined	1. Atlas Drill	1. Atlas X
2. Bethlehem X C L	2. Bethlehem Twist Drill	2. Bethlehem XX
3. Braeburn Standard		3. Braeburn Extra
4. Comet	4. Twist Drill	4. Extra
5. White Label No. 47	5. Twist Drill Red Label	5. Yellow Label No. 46
6. Red Star	6. Colonial Superior	6. Colonial Extra
7. Columbia Tool Steel	7. Columbia Superior	7. Columbia Extra
8. Black Diamond Tool Champion Tool Crescent Tool Labelle Tool Standard Tool Howe-Brown Tool Singer Tool	8. Superior	8. Park-Silver Atha Extra Crescent Extra Labelle Extra Sanderson Extra Howe-Brown Extra Singer Extra
9. Cyclops Cruc ble Cast		9. Cyclops Extra Tool
10. Extra		10. Best
11. Sterling		11. Firth-Sterling Extra
12. Standard	12. Peerless	12. Extra Warranted
13. Cream Label		13. Blue Label
14. Hess Regular	14. Hess Drill	14. Hess Extra
15. Extra Tool		15. Special Tool
17. Standard	17. C F S	17. Extra
18. Elba	18. Salish Arapho	18. Pompton
19. W C S Regular		19. W C S Special
20. Misco		20. Comis
21. Vasco Latrobe		21. Vasco Electric
22. Fort Pitt	22. Superior	22. Extra

FAST FINISHING STEEL	HOT HEADING STEEL	HIGH SPEED STEEL
1. Atlas XXX	1. Atlas Hot Die	1. L-XX
2. Bethlehem Finishing	2. Bethlehem No. 58 Hot Work	2. Bethlehem Special High Speed
3. Braeburn Alloy Finishing	3. Braeburn Alloy Hot Die	3. Braeburn High Speed Special
4. Fast Finishing	4. T K	4. Star Zenith
5. Class K No. 23	5. Otdi No. 9	5. Centurian Superior No. 1 Po-Kip-C No. 3
6. Colonial Best Finishing	6. Colonial H. H. Die	6. Colonial High Speed
7. Columbia Double Special	7. Columbia Phoenix	7. Columbia Clarite
8. Park Double Special Atha Double Special Crescent Double Special Labelle Double Special Sanderson Double Special Howe-Brown Double Special Singer Double Special	8. Peerless "A"	8. Rex "A" Rex "AA" Rex "AAA" Atha Champion
9. Cyclops Alloy A		9. Cyclops B 6 High Speed
10. Fast Finishing	10. H. R. W.	10. Kutkwik
11. Firth-Sterling R T	11. C. Y. W. Choice	11. Blue Chip
12. Double Special	12. L. C. T. Alloy	12. Dreadnought
		13. Peerless
		14. Hess High Speed
		15. Bulldog International Service H. S.
		16. "Ark" Superior "Ark"
17. Extra Special	17. Select	17. Electrite Uranium Electrite-Cobalt Electrite No. 1
18. Iroquois Special	18. Mohawk Hot Work Die	18. Mohawk Extra
19. Finishing Special Finishing	19. Special Bolt Die	19. Extra High Speed Extra High Speed Bits Double Extra High Speed Bits
		20. Simco
21. Vasco Finishing	21. Vasco Marvel	21. Red Cut Superior Red Cut Superior Bits
22. Regal No. 2		22. Wolfram

(*Continued from Page* 263)

ing engineering field with headquarters at the above address. He will continue his relation with the Whitney Mfg. Co., and other local interests. It is his intention to serve the smaller heat treating concern whose production is not sufficient to employ an expert metallurgist continuously. Mr. Rockwell graduated from the Sheffield Engineering School of Yale in 1907 and since that time has had wide metallurgical experience with eastern manufacturing concerns. During the war he was a captain in the Ordnance Corps and district metallurgist. At the present time he is chief chemist and metallurgist of the Whitney Mfg. Co., Hartford, Conn. He is a sustaining member of the American Society for Steel Treating. As a means of introducing himself to future clients, Mr. Rockwell has prepared an interesting 24-page booklet of questions and answers.

A study of the heat treatment of cast nonferrous alloys is to be made by the United States Bureau of Mines at the Pittsburgh experiment station. It is proposed to study the annealing of cast nonferrous alloys for the release of casting strains and the improvement of physical

(*Continued on Page* 35)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

SUPERINTENDENT OR FOREMAN—In heat treating department; 21 years experience in heat treating. Employed at present with large heat treating plant. Desire to make change. Salary desired $3000. Address 10-2.

TECHNICAL GRADUATE—As metallurgist or superintendent of heat treating department. Six years of extensive experience in chemical and physical testing and heat treatment of carbon and alloy steels in automobile and aeronautical motor plants. Best of references. Eastern location preferred. Salary desired $250 per month. Address 11-1.

METALLURGICAL ENGINEER—Columbia University graduate. 7 years experience in steel treating plant, also research department of large steel manufacturing company. Experience included laying out and overseeing commercial heat treatments of small automobile parts, and similar products, and testing of same; design and installation of heat treating equipment; installation and maintenance of pyrometers; research work on high tensile and shock resisting tructural steels, tool steels, magnet steels, etc.; micro examinations and microphotography; magnetic measurements; critical temperature measurements. Salary $200—$250 per month, depending on location. Address 10—3.

HEAT TREATING FOREMAN—Two years pyrometrical and heat treatment of gun forgings; one year heat treatment and physical testing of rolled bar stock, and simple analysis; 1½ years heat treatment, carburizing, and hardening of automobile forgings. Address 9-5.

FOREMAN: 30 years practical experience in heat treating, forging tool hardening, carbonizing. 5 years as foreman of heat treating. Location preferred in Pennsylvania, New Jersey, or Maryland. Salary desired $200 per month. Address 9-3.

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 12-10.

POSITION OPEN

A large spring manufacturer in the Middle West is looking for a young man with technical education, ingenious in the design and construction of new machinery, for position as assistant production manager. Prefers man with some knowledge of automobile spring making. Address: 10-5.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, January, 1922 No. 4

INDICATIONS BESPEAK BETTER BUSINESS FOR 1922

WITH the passing of 1921 an unsatisfactory year for business in general has been recorded in industrial history. As far as the iron and steel industry was concerned, at no time during the twelve months did business approach anything near a normal basis. The slump affected both raw materials and finished products in about the same degree. Production of pig iron fell to a historically low point due to an unusually severe curtailment of operations in June and July. Steel ingot output closely paralleled that of pig iron. The automobile industry which requires large tonnages of castings and many grades of steels has been producing on a greatly reduced plane. All this industrial inactivity has resulted in unemployment and idle equipment.

As unsatisfactory as 1921 may have been, present indications for 1922 bespeak of better business. In the first place, certain national conditions have been improved. Financial needs of the government have been pared sharply and through a still unsatisfactory but moderated tax law, taxes have been lessened both upon private individuals and industry. A suitable tariff law protecting American goods and manufacture is expected to be forthcoming early in the year. As a result of the recent limitation of armament conference, expenditures for naval expansion have been greatly reduced.

Industry once more released from burdensome taxation will be free to pursue its course on a normal basis and with its retrenched policies will be in excellent position to rebuild trade. Hope of reduced freight rates and transportation charges also spurs industrial activity. During the final months of 1921, pig iron and steel ingot production witnessed gradual improvement and an increasing number of inquiries indicated the closing of many orders in the first quarter of the new year. Although no spurt is expected, it is intimated in financial and industrial circles this year will see a gradual recovery to normal conditions.

NEW DEPARTMENT OFFERS INCREASED SERVICE

ANOTHER feature has been added to TRANSACTIONS, that of "The Question Box" which appears on page 346 of this issue. While this department is not new so far as affairs of the local chapters are concerned, it is new in this publication and has been inaugurated with the view of giving increased service to members of the Society. It will appear regularly as a department, its success depending upon the support which it receives. Members of the Society are urged to submit questions as they arise and those in a position to answer questions are requested to submit discussions. Many questions naturally must arise in every day shop practice to say nothing of problems which arise in experimental work in the laboratory. Thus questions

should be forthcoming in sufficient number to warrant the expansion of this department, thereby adding to its field of usefulness. To facilitate handling of "The Question Box," each question will be given a serial number, and members in sending in answers and discussions are requested to refer to these numbers, thus eliminating confusion and errors. In brief the purpose of this new department is to serve as a round table where practical questions may be asked and practical answers and discussions may be returned. Members of the Society are sincerely urged to make this their department, otherwise it must fail from lack of interest.

WILL HONOR INVENTOR OF THERMOCOUPLE

RECOGNITION for his achievements in advancing the heat treating and metallurgical professions to their present day standards is to be given Prof. Henry Le Chatelier by presenting to him on the fiftieth anniversary of his scientific career a suitably inscribed gold medal bearing his effigy. It is widely known, of course, that Professor Le Chatelier is the inventor of the platinum thermocouple, but in addition he has made numerous valuable contributions to science. If for no other accomplishment, the noted French scientist is deserving of proper recognition for development of the thermocouple. In the evolution and advancement of metallurgical operations, the thermocouple has become universal as an accurate means for measuring temperature and with its adoption former rule of thumb methods have become obsolete. The thermocouple with its highly developed registering device, the pyrometer, has had much to do with promoting both quality and quantity production. It is of fundamental importance.

For the purpose of expressing to Professor Le Chatelier the appreciation of the heat treating and metallurgical professions, a French committee has been organized to collect funds for striking and presenting the medal. In order that America may be represented in the movement, a subcommittee of prominent American metallurgists and scientists has been appointed to secure funds in this country. What this committee expects to accomplish and the methods to be used are outlined in detail on another page of this issue. As the date of presentation of the medal will take place in the near future, prompt response is desired. It is to be hoped that members of the American Society for Steel Treating will accept the opportunity for honoring Professor Le Chatelier for his work in advancing their profession.

SET DATE FOR WINTER MEETING

THE Winter Meeting of the Society, or New York sectional meeting, will be held in the Engineering Societies building, 29 West Thirty-ninth street, New York, on Friday, March 3. As yet the program is not completely arranged, however, several technical papers have been secured. A few of them will appear in the February issue of TRANSACTIONS while the balance will be placed in preprint form.

TRANSACTIONS INDEX IS READY

AN INDEX for Vol. I of TRANSACTIONS has been prepared and is now ready for distribution to readers. A copy may be obtained upon request to the National Secretary, 4600 Prospect avenue, Cleveland. It contains the names of 84 authors. For convenience in finding articles, the cross index method has been used, some 300 subjects being listed. To facilitate binding, the index is printed in pamphlet form and the same page size as TRANSACTIONS.

WILL HONOR FRENCH SCIENTIST AND INVENTOR

A MOVEMENT has been started to honor Prof. Henry Le Chatelier, prominent French scientist and inventor by presenting to him a medal bearing his effigy. To assist in this movement, an American subcommittee has been selected to represent the metallurgists, chemists and scientists of the United States, the chairman being Prof. Albert Sauveur. The work of Professor Le Chatelier is of special significance to all heat treaters for to this man must be given the credit for inventing the platinum thermocouple. Members of the Society are given the opportunity to contribute through the blank which is shown below. The committee desires to have the money in hand at the earliest possible moment. Following is a self explanatory letter sent out by the American subcommittee:

To the friends and admirers of Prof. Henry Le Chatelier and to those who have profited by his inventions and his writings.

A number of colleagues, friends and students of Prof. Henry Le Chatelier desire to commemorate the fiftieth anniversary of his scientific career by the casting of a medal bearing his effigy, to be presented to him. An American subcommittee has been organized in order that American metallurgists, chemists and scientists may participate in this testimony to one to whom we owe so much.

It is not desired to send to the French committee from the United States funds in excess of one thousand dollars, although the sum subscribed should be large enough to cover the printing, mailing and other expenses of the committee.

It is believed that those who recognize the great value to science and to the metallurgical and chemical industries of the contributions of Prof. Henry Le Chatelier will be glad of this opportunity to associate themselves with this mark of esteem and admiration. Subscriptions of one to five dollars will be welcome by the committee.

Contributions should be addressed to Bradley Stoughton, 29 West 39th Street, New York.

If you desire to subscribe, kindly sign the enclosed slip, but do not indicate on it the sum subscribed. These slips will be forwarded to Professor Le Chatelier, and the committee hopes that it will be able to secure at least one thousand of them.

I desire to associate myself with the presentation of a medal to Professor Henry Le Chatelier, member of the Institute of France, as a token of admiration for his work, and of gratitude for the benefits it has bestowed on the scientific and industrial world.

Name.....

Address.....

Position.....

SELECTS NOMINATING COMMITTEE FOR 1921-1922

PRESIDENT F. P. GILLIGAN, of the American Society for Steel Treating, has announced the appointment of the Nominating Committee for the selection of national officers for the year 1921-1922.

The personnel of this committee is as follows:

Chairman, D. W. McDowell, chief inspector, Jones & Laughlin Steel Co., Pittsburgh, Pa., and Secretary of the Pittsburgh Chapter.

The members of this committee are:

H. C. Goodwill, superintendent of dies, R. Wallace & Sons Mfg. Co., Wallingford, Conn., and Chairman of the New Haven Chapter.

W. J. Priestley, superintendent of hot metal department, United States Naval Ordnance Plant, South Charleston, W. Va., and Chairman of the Charleston Chapter.

C. W. Schumann, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, Ill., and ex-secretary of the Chicago Chapter.

C. S. Moody, metallurgical engineer, Minneapolis Steel & Machinery Co., Minneapolis, Minn., and ex-chairman of the Northwest Chapter.

This committee will announce its selection of candidates for national officers in June. These new officers will be elected by mail ballot sent to the members of the Society and will assume their offices during the 1922 National Convention at Detroit, Sept. 25 to 30.

Voting members of the Society are requested to recommend to the committee the names of eligible persons for the elective offices.

EDUCATIONAL PROGRAM RECEIVES ENDORSEMENT

CONSIDERABLE attention has been attracted to the educational program which various chapters of the American Society for Steel Treating have initiated during the past few months. So far as its educational work is concerned, the Society today probably is leading the field. This policy has been endorsed by the *Iron Age* which in its Dec. 1 issue speaks editorially as follows:

"A unique development in the work of the American Society for Steel Treating had its inception last year in one of the New England districts where certain chapters started an educational program at their monthly meetings. This year the movement has so far expanded that the society may be said to take the lead in active educational work among its members. A conspicuous example is the Philadelphia chapter, which has organized an evening course in metallurgy and heat treatment at Temple University. In the New York chapter a series of monthly meetings has been arranged, the program for which contemplates a progressive course in steel metallurgy and heat treatment. Each month an authority in a particular line gives the chief lecture, which is followed by questions and discussions. Brief abstracts are given also of the principal articles on metallurgical subjects in the technical press. Other local chapters are adopting similar plans. Fostered by the national board of directors and by visits of the national president to local chapters, the departure promises greatly increased interest in the work of this enterprising society."

SOME BRINELL HARDNESS MEASUREMENTS ON SMALL SPECIMENS

By E. D. Campbell

THE value of knowing the Brinell hardness number of steel has been recognized for so many years that this method of testing has become almost universal. For the harder class of metals, such as steel, a standard condition of testing, using a 10-millimeter ball with a load of 3000 kilograms has been adopted generally, while for soft metals the same sized ball under a load of 500 kilograms is used. To insure accuracy of results when working under standard conditions, the width of the test specimen should not be much, if any, less than twice the diameter of the ball, nor the thickness much less than the diameter. The scleroscope has been found satisfactory for testing many small specimens and thin plates or sheets. During the war some new forms of Brinell machines, adapted for use with small balls only and a very light load, intended for testing thin sheet brass, such as cartridge cases, were perfected. Special devices were required for measuring the diameters of the impressions made with these small balls and new tables had to be computed to convert the values obtained into Brinell hardness numbers.

In the course of the researches on the constitution of steel, which have been carried on in this laboratory during the past 30 years, it has been found during the last 6 or 7 years that small bars about 6 millimeters square and 15 centimeters long are better adapted to the facilities available, both for heat treatment and measurement of such properties as specific resistance, thermal resistivity, thermoelectromotive potential, etc., than any other size tried. Six or seven years ago a standard Alpha Brinell machine was imported and has been in regular use whenever specimens were large enough to be tested under standard conditions.

The object of the present paper is to describe an attachment for the standard Alpha Brinell machine, which attachment has been in use in this laboratory for the past two or three years and enables hardness measurements to be made on small bars with almost as much ease and accuracy as can be done on larger specimens, working under standard conditions. In Fig. 1 are shown, in addition to the large regular balance, corresponding to a pressure of 500 kilograms on the ball, the light balance giving 95 kilograms pressure; two weights giving an additional 21 kilograms and three holders for balls of 10, 5, and 2-millimeters diameter.

The principle involved in working out the light balance was that if a small ball—2-millimeters being adopted—were pressed into a smooth surface of given hardness and the image of the impression observed when a 16-millimeter objective is substituted for the 48-millimeter regularly supplied with a Brinell microscope, there must be some pressure which applied to the 2-millimeter ball would give an impression which viewed through the 16-millimeter objective would appear the same size as an impression made with a 10-millimeter ball under 3000 kilograms load on the same surface, but observed through the 48-millimeter objective.

An approximate calculation of the weight necessary for a light balance, was computed from the following data. The large balance, equivalent to

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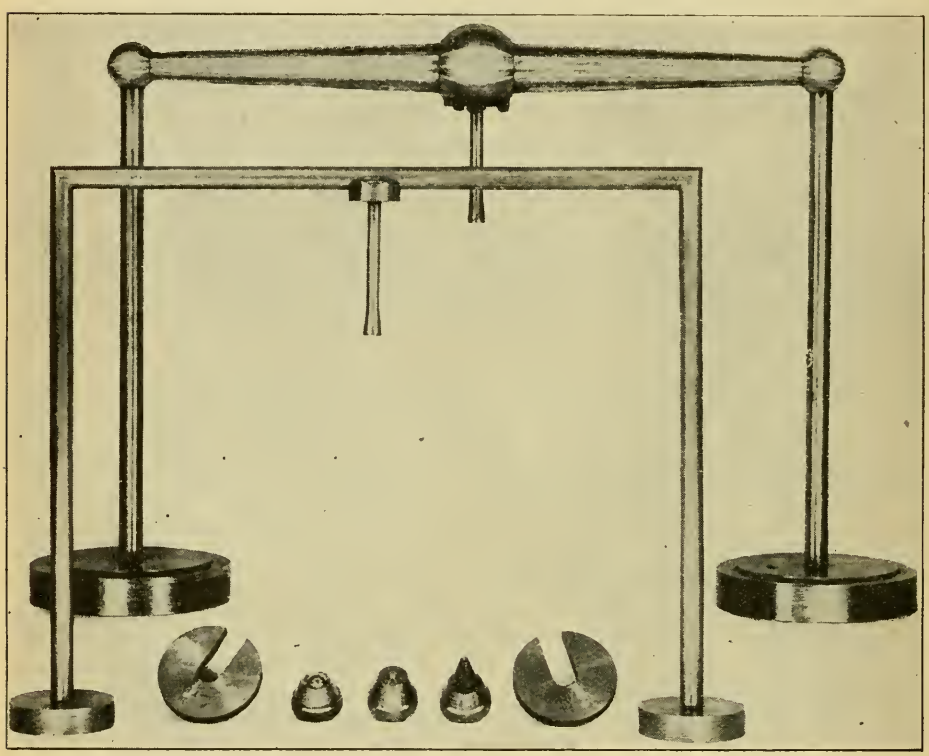
A paper presented by title at the Indianapolis Convention. The author, E. D. Campbell, is professor of chemistry, University of Michigan, Ann Arbor, Mich., and an honorary member of the American Society for Steel Treating.

500 kilograms, weighed 3944 grams or a little less than 7.9 grams for each kilogram pressure. When the 16-millimeter objective was substituted for the 48-millimeter, the magnification was increased 5.75 times. The pressure, therefore, which it would be necessary to apply to a 2-millimeter ball, would be approximately 3000 $(5.75)^2$ or very nearly 91 kilograms. In order to allow for possible friction of the piston, etc., a balance was constructed from light brass tubing, the whole weighing a little over 800 grams or equivalent



LARGE REGULAR BALANCE FOR ALPHA BRINELL MACHINE, LIGHT BALANCE GIVING 95 KILOGRAMS PRESSURE, TWO WEIGHTS GIVING ADDITIONAL 21 KILOGRAMS AND THREE HOLDERS FOR 10, 5 AND 2-MILLIMETER BALLS

to something over 100 kilograms. A piece of steel of uniform hardness and large enough to use under standard conditions was then carefully polished and duplicate impressions made with a 10-millimeter ball under 3000 kilograms pressure. The light balance was then submitted for the regular one and the 2-millimeter ball substituted for the 10-millimeter. An impression made with the 2-millimeter ball with the light balance was then observed through the 16-millimeter objective. The impression appeared, as was expected, a little larger than the standard observed through the 48-millimeter objective. The light balance was then removed, the weight dressed down a little, and the balance again tested as before. The light balance was thus experimentally calibrated until finally, when the weight had been reduced to an equivalent of 95 kilograms, the image obtained with the 2-

millimeter ball under 95 kilograms observed through 16-millimeter objective exactly coincided with that obtained with the 10-millimeter ball under standard conditions.

Comparisons were then made through a wide range of hardnesses, from that of ingot iron to freshly hardened hyper-eutectoid steels, the results obtained agreeing equally well through the whole range. In order to obtain close agreement, it would of course be necessary that each instrument be calibrated individually in accordance with the relative magnifying power of the objectives used. If the instrument is thus calibrated, the tables of hardness numbers computed for the 10-millimeter ball under 3000 kilograms may be used equally well when the hardness is measured with a 2-millimeter ball under 95 kilograms, but the image observed with the 16-millimeter objective.

In order to adapt the instrument to the measurement of soft metals such as are ordinarily measured with the 10-millimeter ball and 500 kilograms pressure, the following changes were made. A carefully polished surface of pure annealed copper was used in calibrating. Duplicate impressions were made on this with a 10-millimeter ball and 500 kilograms and observed in the usual manner. A 5-millimeter ball was then substituted for the 10-millimeter and an impression made with the 95 kilogram balance. When this latter impression was observed through a 32-millimeter objective, which would increase the magnification 2.20 times as compared with a 48-millimeter objective, it appeared somewhat too small. Ordinary weights were then added to the balance, new impressions made and observed through the 32-millimeter objective until it was found that the addition of weights equivalent to 21 kilograms would give an impression which when observed through a 32-millimeter objective, exactly coincided with that from a 10-millimeter ball under 500 kilograms and measured in the usual way. By using a 5-millimeter ball under 116 kilograms pressure and observing through a 32-millimeter objective, the same hardness tables, giving values for a 10-millimeter ball under 500 kilograms pressure, may be used.

To obtain the most satisfactory results when using a 2-millimeter ball with the light balance, a number of conditions should be observed. By rubbing a little heavy grease in the hemispherical depression of the holder and then pressing the ball in, the latter will have no tendency to fall out when in use. Magnetizing the holder causes the ball to leave the depression and seek the edge of the holder. The surface to be tested must be polished almost the same as for metallographic work, although some very fine scratches are often useful in detecting the outline of the depression, since the pressure of the ball produces a perfect polish in the depression itself. When the surface to be tested has been polished, it should be rubbed over with a slightly oily cloth, to lessen the friction between the ball and the surface of the metal being tested. When making an impression, the pumping up to the point where the balance rises should be done slowly and carefully to avoid any temporary excess of pressure, and when the pressure is up to that indicated by the balance, it should be held at this point at least 1½ minutes to insure equilibrium. On account of the small size of the impressions and the use of a 16-millimeter objective, it is necessary to use a fine adjustment in order to focus. For this purpose the tube of the Brinell microscope may be placed in an ordinary microscope stand and a mechanical stage may be used for moving the specimen until the impression is in position for focusing and reading the diameter. Strong daylight gives decidedly

the most satisfactory illumination, but when this is not practicable oblique illumination from two lamps, one on each side of the specimen, may be used.

About a year ago, in an article on "Notes as to Rates of Reaction in Certain Steels at 930 Degrees Cent.," (Journal Iron and Steel Institute, 1920, No. II, page 281), the author submitted experimental evidence which showed that when bars 6 millimeters square and 15 centimeters long were quenched

TABLE I

Composition of Steels and Quenching Temperatures

Steel No.	Quenching temperature degrees Cent.	Composition weight, per cent Carbon	Mang.	Phos.	Sulphur	Silicon	Nickel	Chrom.	Tungs.	Iron
1*	938	.076	.122	.03	.017	3.65	...	...	...	96.10
2	897	.133	11.57	.055	.026	.25	...	...	...	88.00
3*	938	.036	.677	.038	.020	.231	2.80	...	...	96.2
4*	940	.027	.405	.013	.018	.162	4.48	...	...	94.9
5*	930	.035	.38	.007	.003	.45	...	1.40	...	97.7
6	897	.026	.32	.018	.006	.12	...	.24	5.04	94.2
7*	930	.23	.27	.02	trace	.88	...	14.32	...	84.3
8	840	.68	.37	.015	...	.29	...	.32	5.50	92.8
9	906	.35	.08	.009	.024	.018	...	...	...	99.3
10	910	.76	.22	.016	.041	.169	...	...	...	98.8
11	910	1.39	.27	.021	.015	.16	...	...	...	98.1

*Indicates bars tempered 110 degrees Cent, iron determined by difference.

in cold water, the rate at which the section first entering the water passed through the critical range must have been slower than at which the last section, No. 15 passed through the same temperature range, since there was enough difference in the concentration of the carbides remaining in solution to produce an easily measurable difference in thermoelectromotive potential at the two ends of the bar.

Since Brinell hardness is due largely to a state of strain, the amount of which strain is influenced by both the carbide concentration at the instant of quenching and the rate at which the metal passes through the critical range, it was thought that perhaps some further light might be thrown on this subject by measuring the hardness at both ends of a number of steels with widely varying carbide concentrations. Eleven steels, in the form of bars 6 millimeters square and 15 centimeters long, were selected for the work. The first six were steels which had been decarburized with hydrogen according to a method described in an article by the author on "The Decarburization of Steel with Hydrogen," (Journal Iron and Steel Institute, 1919, No. II, page 407). The seventh was a high chromium stainless steel; the eighth, a special magnet steel; while the last three were straight carbon steels, differing widely in carbide concentration. The compositions of these steels together with temperatures of quenching are shown in Table I.

After the heat treatment, the ends of the small bars were ground carefully and polished. Two heavy steel blocks, which had been used as a mold, served as a holder for the small bars while the Brinell impressions were being made. As in the paper on "The Rates of Reactions in Certain Steels at 930 Degrees Cent.," these bars should be considered as being made up of fifteen sections, each 1 centimeter long, Section 1 being the end of the bar first touching the water and Section 15 the last. The total time required for complete immersion of the bar, from the time Section 1 touched, did

not exceed probably 1/10 of a second, and the time required to cool from the quenching temperature to the time no color was visible, was from 4/5 of a second to 1 second. The total time from the time of quenching until the bars were down to bath temperature, was from 5 to 6 seconds. The results of the Brinell measurements at the two ends of the bars, and the average hardness are given in Table II.

A study of the data in Table II shows that in the strongly hypoeutectoid steels, Nos. 3. 4, 5, 6, 7, and 9, whether nickel, chrome, or straight carbon steels, the rate of transformation of the gamma to the alpha form is so rapid that the difference in the rate of cooling between Section 1 and Section 15 is enough to make a measurable difference in the amount of metal trapped in the transition state, hence in the degree of strain set up. This is indicated by the greater hardness of Section 15 as compared with Section 1.

As has been known for many years, when manganese is atomically substituted for iron, it tends to retain the metal in the gamma or nonmagnetic state. In steel No. 2, although the carbide concentration is quite low, the effect of the high manganese in suppressing the rate of transportation of the gamma to the alpha state, is sufficient so that the difference in the rate

Table II

Brinell Measurements at Opposite Ends of Bars

Steel No.	Carbon per cent	Quenching temperature degrees Cent.	Brinell hardness number Section 1	Section 15	Average
1	.076	938	228	187	207
2	.133	897	364	364	364
3	.036	938	286	302	294
4	.027	940	202	228	215
5	.035	930	183	207	195
6	.026	897	156	241	198
7	.23	930	311	364	337
8	.68	840	713	713	713
9	.35	906	418	512	465
10	.76	910	600	600	600
11	1.39	910	782	782	782

of cooling of Section 1 compared with Section 15 is not noticeable, the bar having the same degree of hardness at both ends.

Since the effect of increasing the carbide concentration is also to suppress the rate at which the gamma iron transforms into the alpha condition, by this time the carbide concentration approaches the eutectoid point, as in samples 8, 10 and 11, the effect of this retardation is also great enough so that the difference in rate of cooling between Sections 1 and 15 is not noticeable and the bars have the same hardness at both ends.

These hardness measurements therefore seem to confirm the conclusions concerning rates of reactions in steels at high temperatures, drawn from the previous studies on thermoelectromotive potential.

PREPARING TOOL STEEL AT THE MILL

By A. W. F. Green

MANUFACTURE of tool steel embodies a number of operations starting with the melting and continuing through the blooming, pressing, hammering, rolling and annealing processes. The quality of the product is determined by the amount of care exercised in the selection of raw materials used in the melting process, and all subsequent operations.

The chief considerations of this article are the effects of proper finishing temperatures in the hammer shop and rolling mill on the steel, and the normalizing and annealing of the product. It is not possible in this short discussion to go into detail concerning the other operations which have been outlined. Discussion is limited to straight carbon and one or two alloy steels exclusive of high speed steel.

Hammering of tool steel may be divided into two separate operations, namely, cogging down, and finishing to a size. It is often the case that the two processes are completed with but one heating of the material. Cogging down consists in heating an ingot, bloom or billet to a suitable temperature, from 1800 to 2100 degrees Fahr., depending upon the temperature at which hammering is to be stopped, and breaking it down into multiples of a size which may be more easily handled in the rolling mill or under smaller hammers. Cogging down usually is accomplished with hard blows of the hammer, the finishing temperature being generally in excess of the Ar range of the material, 1400 to 1600 degrees Fahr. After cogging down to the desired size and shape, the pieces are allowed to cool, in the air, or in lime, ashes, etc., so that normalizing or partial annealing are accomplished without placing the material in special furnaces for that purpose.

Finishing to a size is done by reheating the cogged down pieces to a suitable temperature, 1800 to 2000 degrees Fahr., and then working them down to the desired size and shape. The blows at first are delivered hard, and as the material approaches the size and shape needed and also becomes colder, are increased in speed and made lighter so that the steel will not be ruptured and will be put into good condition structurally. "The colder the material is finished, the closer to the exact size it can be made, because it has less shrinkage to undergo; but it will be harder, less ductile and stronger."[2] Slow cooling in lime, ashes, etc., is sometimes done so that a certain amount of annealing or normalizing may take place.

Although it is certain that normalizing or annealing does take place to some extent when hammering is followed by air cooling from a temperature at or above the critical Ar range of the steel, it is often the case that but relatively small areas are benefited. There are several reasons why this is so. "The principle of the hammer is that of an almost instantaneous application of pressure applied to a relatively small area. This makes hammering a slow process of reduction but results in a more uniform and better working of the crystals on the surface at least, which is one of the chief reasons for the superiority of hammered over rolled material".[2] Thus if hammering is stopped at a temperature from which normalizing or annealing is possible, it is evident that the structural conditions of the ex-

1. "Metallurgy of Iron and Steel," by Stoughton.
2. "The Making, Shaping and Treating of Steel," by Camp.

A paper presented at the Indianapolis Convention. The author, A. W. F. Green, is chief of laboratory, John Illingworth Steel Co., Philadelphia.

terior and the interior of the material are different. This is illustrated by photomicrographs in Figs. 3 and 4, which were taken from a steel containing 1.20 per cent carbon and 1.25 per cent tungsten after being hammered. Fig. 3 represents a section of the material taken along the surface, while Fig. 4 shows a section of the center of the same bar. It will be noticed that in the latter section, evidence remains of the original ingot structure in the needles of free cementite within the grain boundaries and which are entirely in solution in the grains making up the exterior portion of the material. Thus, it is evident that to secure the best effects of normalizing or annealing, the steel should be given a separate treatment than that which may be given by regulating the cooling from the finishing temperature.

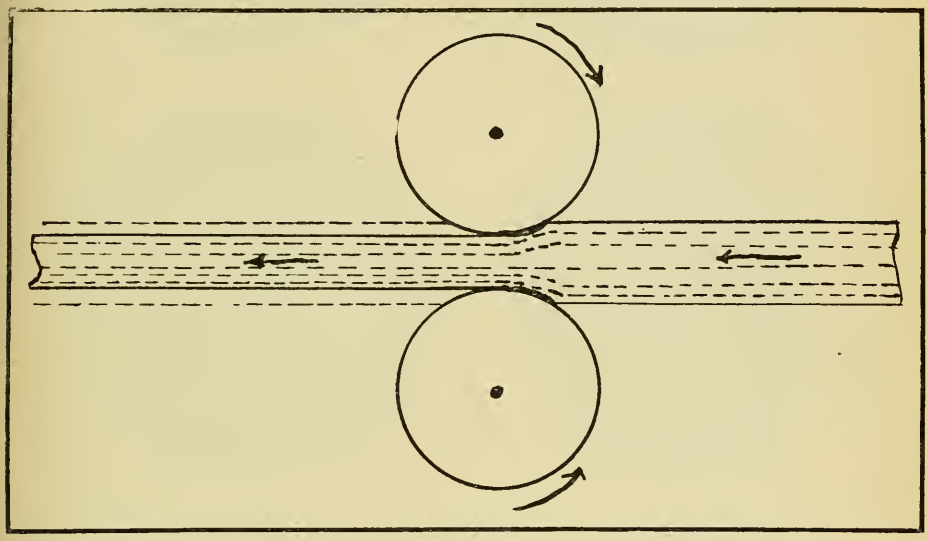


Fig. 1—Diagram illustrating the action of the rolling mill on material passing through. Drawing taken from Camp.

The chief effects of hammering, therefore, are gained by control of the heating and finishing temperatures of the steel as related to time, mass, surface, and the size of the hammer. Care must be exercised at all times to keep the furnaces used free from cutting flames and severely oxidizing atmospheres. To illustrate the effects of improper furnace conditions on structure, reference is made to Figs. 5, 6, 7 and 8. In Fig. 5 is shown the cast structure of a steel containing 0.50 per cent carbon, and 1.50 per cent nickel. This steel when properly heated for hammering and finishing correctly, has a structure as shown in Fig. 6. When undue blast and intense flame is used for quick heating, and the steel is improperly cared for, structures such as shown in Figs. 8 and 6 result. Fig. 7 also shows some of the effects of the severe decarburization which may take place.

Rolling of tool steel also may be divided into two operations, namely, cogging down, and finishing. However, because of the speed with which these operations are carried on and usually without the necessity for two heatings, it is difficult to draw a sharp line between them.

"The process of shaping steel by rolling consists essentially of passing the material between two rolls revolving at the same peripheral speed and in opposite directions, that is clockwise and counter-clockwise, and so spaced

that the distance between them is somewhat less than the height of the section entering them."[2] Various forces are, therefore, brought to bear upon the metal entering the rolls and are demonstrated somewhat by the drawing shown in Fig. 1, after Camp. "The exact crystalline action that takes place under mechanical treatment is not known. In the case of rolling, Professor Howe has tentatively assumed the conditions graphically shown in Fig. 2 in which the abscissa line represents the size of grain at the different temperatures. At 2550 degrees Fahr. the grain size is represented by the hori-

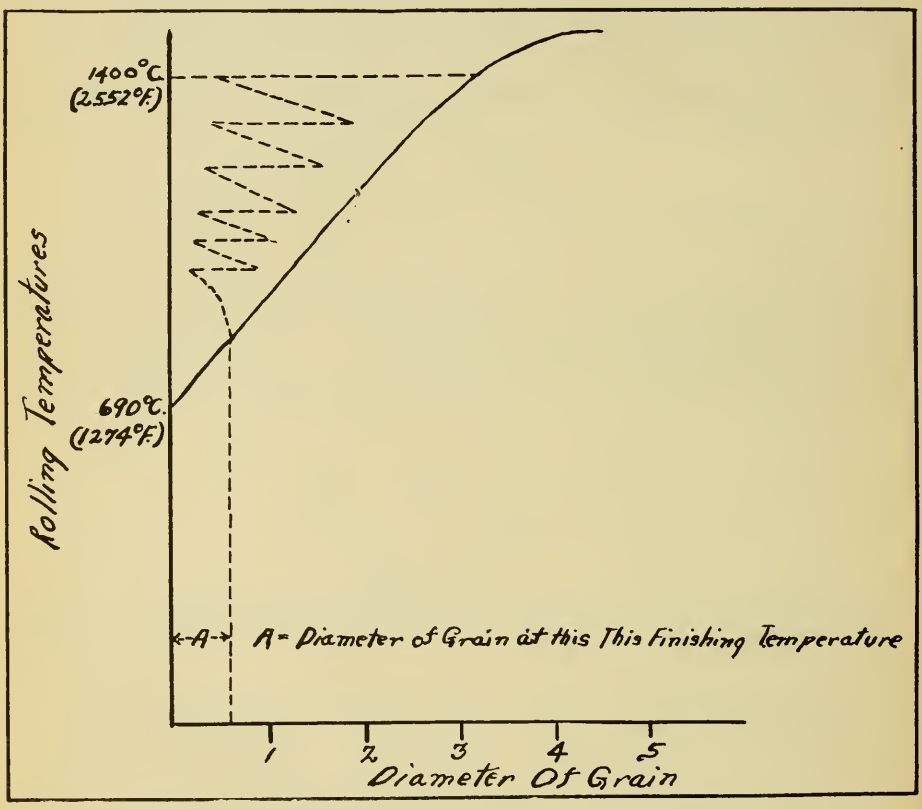


Fig. 2—Graphical representation of grain size at the different temperatures as steel receives passes through the rolling mill. Reproduced from Howe's "Iron, Steel and Other Alloys."

zontal dotted line from vertical axis. On the first passage through the rolls the grains are crushed to a very small size, but on emerging again they grow rapidly. Meanwhile, however, the metal has been cooled, and this fact, as well as the inability of the grains to grow constantly, causes the new size of grain to be smaller than before. Therefore, each passage through the rolls renders the crystals smaller in size, the final size depending upon the temperatures and the amount of reduction in the last pass."[2] It is quite evident that to place rolled steel in the best condition for future use, rolling must be followed by normalizing or annealing or both of these treatments.

The temperatures to which steel is heated for rolling are generally in excess of those employed for hammering, namely 2000 to 2400 degrees Fahr. and consequently because of the process it is a great deal

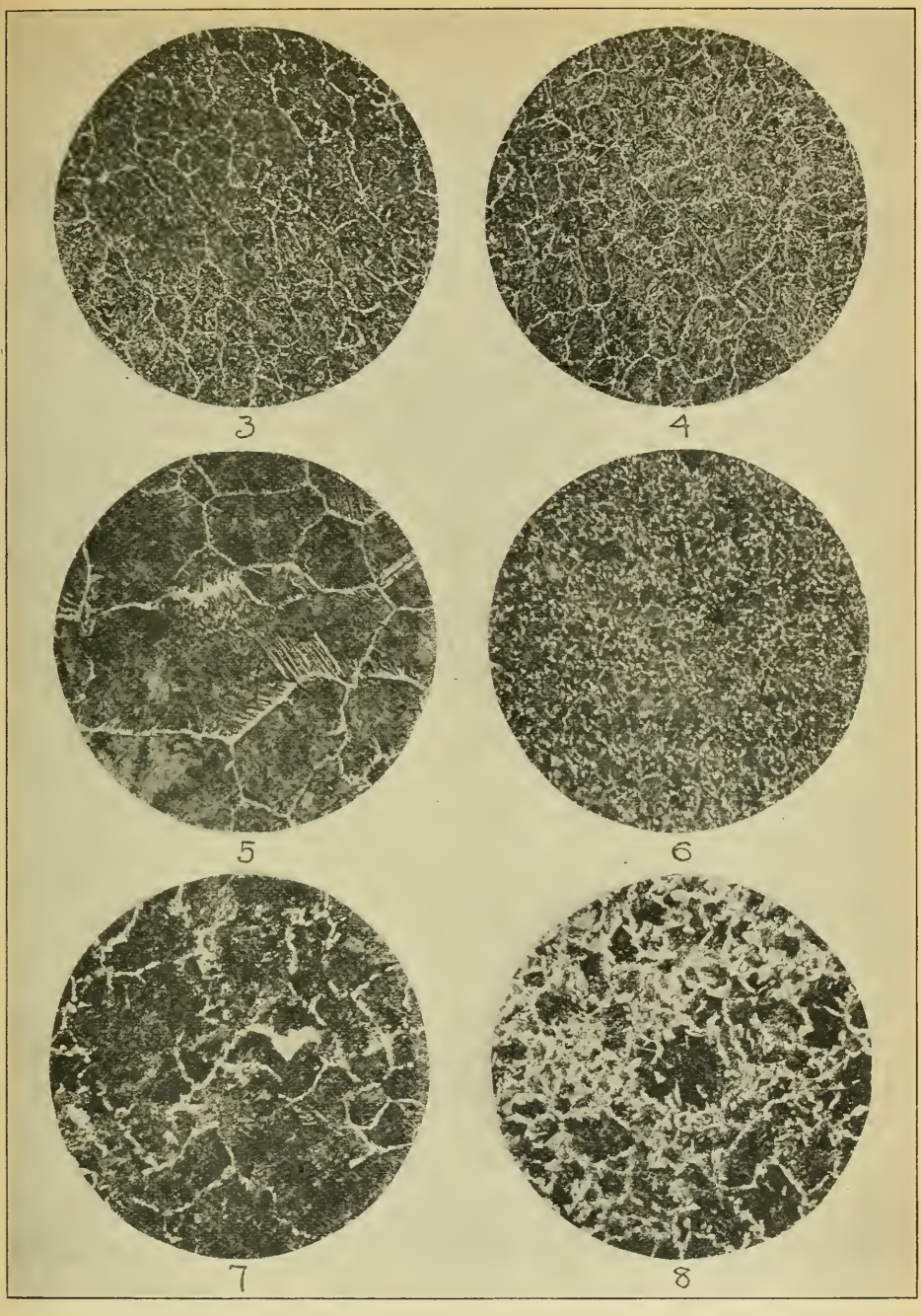


Fig. 3—Structure on surface of 1.20 per cent carbon, 1.25 per cent tungsten forged bar. Etched with 10 per cent nitric acid and X 120. Fig. 4—Structure in center of same bar shown in Fig. 3. Etched with 10 per cent nitric acid and X 120. Fig. 5—Cast structure of 0.50 per cent carbon, 1.50 per cent nickel steel. Etched with picric acid and X 120. Fig. 6—Structure of correctly hammered bar of same steel shown in Fig. 5. Etched with picric acid and X 120. Fig. 7—Structure of same steel as Fig. 5 improperly heated for hammering. Etched with picric acid and X 120. Fig. 8—Structure of same steel as Fig. 5 improperly heated and showing excessive decarburization. Hammered structure. Etched with picric acid and X 120.

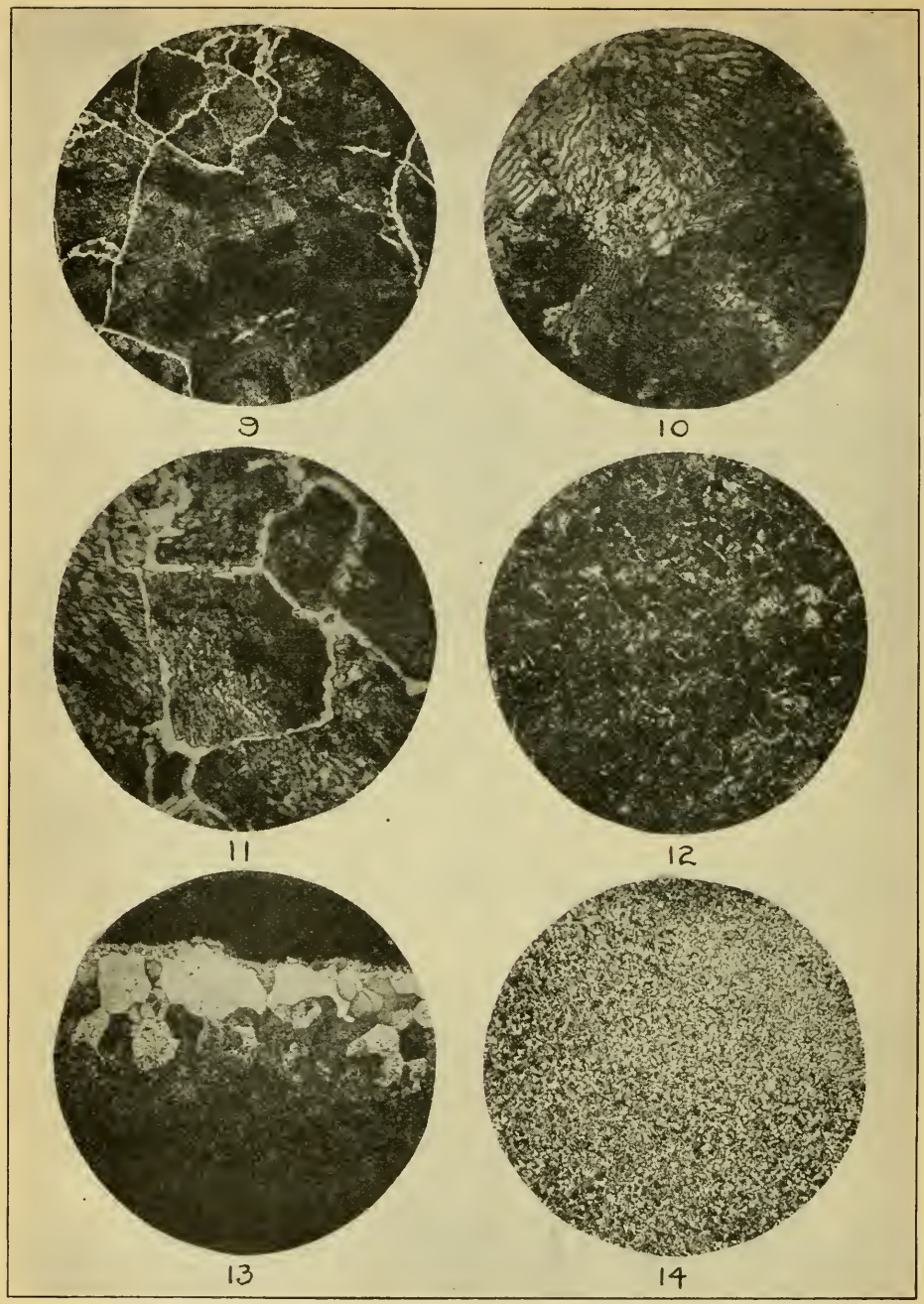


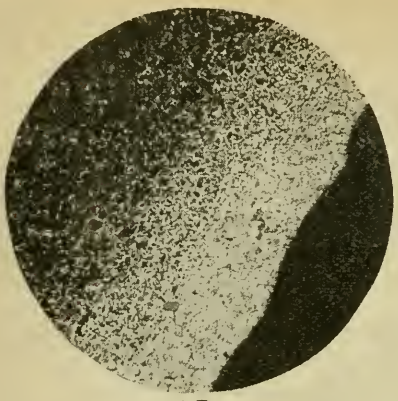
Fig. 9—Structure of 1.10 per cent carbon tool steel due to severe overheating in mill furnace. Etched with 10 per cent nitric acid and X 120. Fig. 10—Structure of 0.80-0.90 per cent carbon tool steel heated too high for work to be done in rolling mill. Etched with 10 per cent nitric acid and X 500. Fig. 11—Structure of 1.05 per cent carbon tool steel which has been heated too high in rolling mill furnace. Etched with 10 per cent nitric acid and X 500. Fig. 12—Structure of 1.05 per cent carbon tool steel heated 300 degrees Fahr. less than that shown in Fig. 11 and then rolled. Etched in 10 per cent nitric acid and X 120. Fig. 13—Structure of 0.80-0.90 per cent carbon tool steel showing excessive decarburization due to improper heating in mill furnace. Etched with picric acid and X 120. Fig. 14—Structure of 1.10 per cent carbon tool steel seriously decarburized in rolling mill furnace. Etched with 10 per cent nitric acid and X 120.

harder to control the finishing temperatures, or the temperatures at which rolling is stopped. These temperatures are dependent upon the kind of material being rolled, the size of the ingot or billet, the size and speed of the mill, and the number of passes employed in reducing the steel to the desired shape and size. A good illustration of this is shown in the rolling of two billets four inches square and weighing 160 pounds each. One contains 1.10 per cent carbon and the other 0.10 per cent carbon. Both are rolled to a 1-inch round section with eight passes in the mills. The temperature for rolling the first billet will approximate 2000 degrees Fahr., while the second or low carbon billet will be rolled from a temperature of about 2400 degrees Fahr.

Efforts are being made to obtain better control of heating temperatures for rolling mill work by the use of continuous billet heating furnaces in which furnace design and temperature control apparatus play an important part. It is necessary that the heater on a rolling mill furnace be an experienced and trustworthy man. His experience serves him in that he is able to give steels of varying chemical content the correct heating for the work to be given it in the mill. The effects of improper heating are shown to some extent in the photomicrographs of Figs. 9, 10 and 11. Fig. 9 represents the finished structure of a steel which was to have been used for making threading dies, containing 1.10 per cent carbon. Investigation showed that the steel had been placed in the furnace in such a way that it was exposed to a very hot flame, and after firing up the furnace the heater decided to go on a strike which lasted for three hours, and resulted chiefly in the ruination of the steel in the furnace. Fig. 10 shows the structure of an 0.80-0.90 per cent carbon tool steel which had been heated too high for the work to be done—the finished size was over 1½ inches in diameter—thus being finished at too high a temperature. Fig. 11 shows a steel containing 1.05 per cent carbon which had also been heated too high. Fig. 12 is the photomicrograph of a steel containing 1.05 per cent carbon which had been heated 300 degrees Fahr. less than that shown in Fig. 11 and finished at the correct temperature.

However, there is another serious defect which results from improper heating in the rolling mill furnace, and that is decarburization. Fig. 13 shows the decarburization occurring in 0.80 to 0.90 per cent carbon tool steel which has been exposed to a cutting flame and in a severely reducing atmosphere. Fig. 14 shows the same condition, but the effect is much more serious in that the carbon has been extracted to a greater depth by long heating in the rolling mill furnace under adverse conditions. Fig. 15 represents the decarburized structure of sheet steel used in the manufacture of knife blades, the effect being so serious that the steel had to be pickled in order that the oxide or scale would be removed from the decarburized surface, so that when the steel was reheated the new oxide would be formed of a good portion of the free iron of the low carbon area. This scale peeled off during finishing in the mill.

Figs. 16, 17, 18 and 19 represent a series showing the make-up of steel as it enters the rolling mill furnace and some of the structures subsequently produced. Fig. 16 shows the cast structure and Fig. 17 the structure of the steel as it comes from the cogging down rolls where it receives three passes in being reduced from a 4-inch square to 1½-inch square. Fig. 18 shows the finished structure of the steel. Fig. 19 shows the structure of file steel which had been finished at too high a



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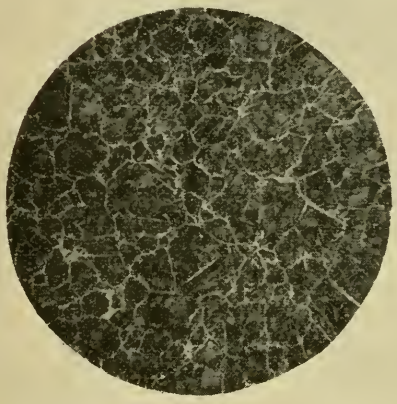

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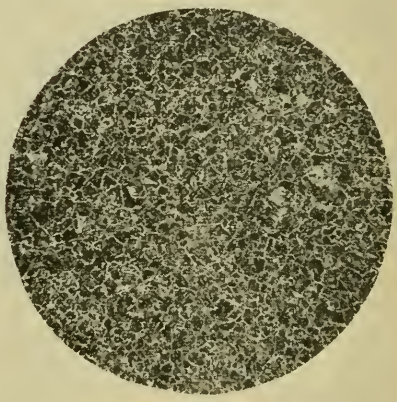

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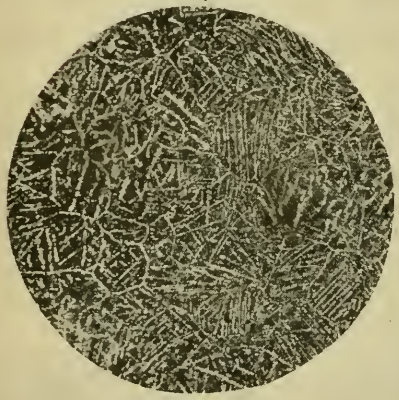

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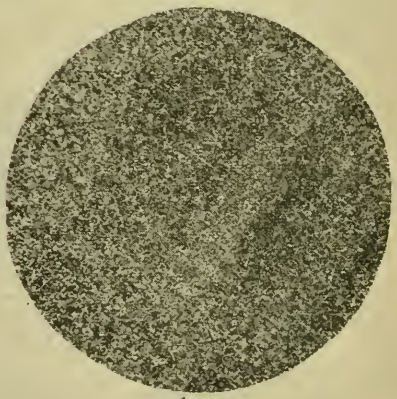

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Fig. 15—Structure of 1.15 per cent carbon knife blade steel seriously decarburized in mill furnace. Etched with 10 per cent nitric acid and X 120. Fig. 16—Cast structure of 1.40 per cent carbon file steel. Etched with 10 per cent nitric acid and X 120. Fig. 17—Structure of file steel of Fig. 16 after being cogged down in three passes, evidences of cast structure still showing. Etched with 10 per cent nitric acid and X 120. Fig. 18—Structure of file steel as it comes from the rolls finished properly and at correct temperature. Etched with 10 per cent nitric acid and X 120. Fig. 19—Structure of file steel finished at too high a temperature and then hardened. Etched with 10 per cent nitric acid and X 120. Fig. 20—Structure of file steel correctly finished in rolling mill and then hardened. Etched with 10 per cent nitric acid and X 120.

temperature and then hardened, and Fig. 20 represents the hardened structure of file steel which has been properly treated and correctly finished in the mill.

From the foregoing it is quite evident that the lack of care in the rolling mill can make the work of the tool steel worker and heat treater very difficult, and also that temperature control is of the utmost importance in the rolling of steel. The finishing temperature is under greater control in the hammering process than in rolling, as stated previously, because the conditions which go to make up the two operations are vastly different. The best temperature for the finishing of rolled steel is at the Ar range of the steel. This may be determined in a number of ways, but probably the simplest means is by the magnet and the condition of the scale. The use of the magnet is based on the magnetic properties of steel above and below the critical stage, since steel above the range is nonmagnetic. The change represented being from the alpha to gamma state. The other method based on the condition of the scale or oxide on the steel, is that when steel has passed through the Ar range, the scale will not lift from its surface during further cooling.

Microscopically the finishing temperatures of steel may be determined by the structure of the cold material, after cooling on the mill floor. Figs. 21, 22, 23, 24 and 25 show the structural conditions of a steel containing 1.10 per cent carbon and finished at different temperatures, with the exception of Fig. 25 which shows the finished structure of a steel containing 1.10 per cent carbon and 1.60 per cent chromium. It has been found that in those cases where the finishing temperature has been so regulated as to produce a sorbitic structure as shown in Figs. 23, 24 and 25, that a simple anneal at a temperature under the critical range is sufficient to produce a high grade annealed tool steel of the kind best suited for the tool maker and treater.

As previously stated normalizing or annealing or both of these treatments are necessary if tool steel is to leave the steel mill in the best condition. Efforts have been made to show why this is so. Normalizing is especially necessary in steels containing alloys such as chromium. One evidence of this fact is seen by referring to photomicrographs, Figs. 26 and 27. Fig. 26 represents the structure of a chromium carbon steel containing 1.72 per cent chromium and 1.34 per cent carbon after being hardened. The steel was first hammered to size, heated to 1600 degrees Fahr. for several hours and slowly cooled in the furnace after which it was hardened. Fig. 27 shows the structure in another place of the same material which was hammered to size, air-cooled, then heated to 1650 degrees Fahr. and air cooled or normalized, and then annealed at 1600 degrees Fahr., or slowly cooled in the furnace and then hardened. The structure in Fig. 26 was produced in hammering and comprises areas of free carbides which did not go into solution with the rest of the material under ordinary annealing. The finishing temperature of the steel was slightly in excess of the Ar range. In Figs. 28, 29 and 30 are shown the structures of chromium carbon steel containing 1.30 per cent carbon and 1.60 per cent chromium which was normalized after hammering and then annealed. Fig. 28 was heated to 1800 degrees Fahr. slowly cooled in the furnace to 1100 degrees Fahr. and then air cooled. Fig. 29 was heated to 1550 degrees Fahr. after hammering and cooled in the furnace, while in Fig. 30 the structure

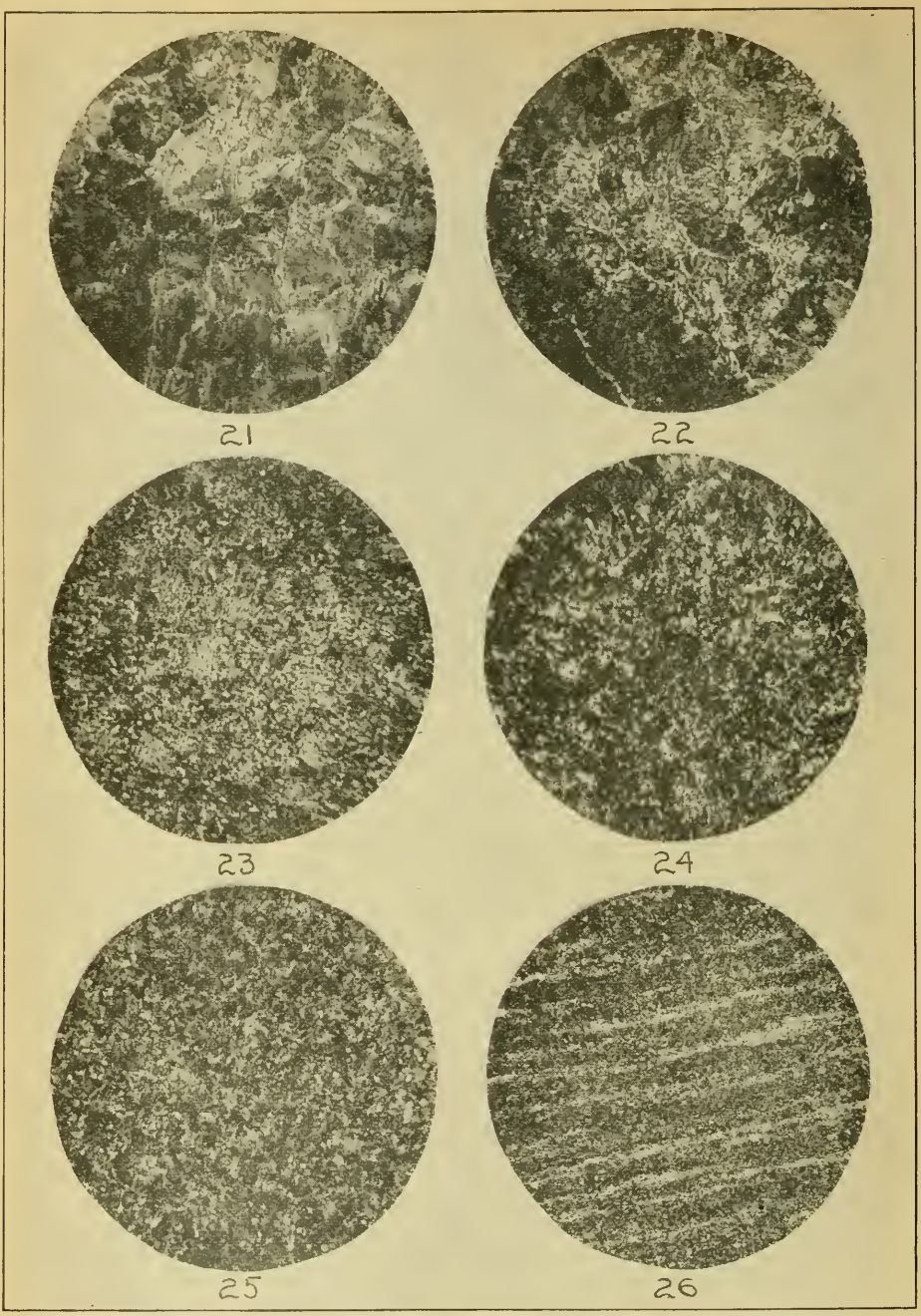


Fig. 21—Structure of 1.10 per cent carbon tool steel finished above the Ar range and showing a pearlitic structure with free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 22—Structure of 1.10 per cent carbon tool steel finished above the Ar range showing pearlitic condition with some sorbite and free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 23—Structure of 1.10 per cent carbon tool steel finished at or near the Ar range showing sorbito-pearlitic condition with little free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 24—Structure of 1.10 per cent carbon tool steel correctly finished at Ar range showing wholly sorbitic condition. Etched with 10 per cent nitric acid and X 500. Fig. 25—Structure of 1.10 per cent carbon, 1.60 per cent chromium tool steel correctly finished in rolling mill. Sorbitic condition. Etched with 10 per cent nitric acid and X 120. Fig. 26—Structure of 1.34 per cent carbon, 1.72 per cent chromium tool steel hardened showing effects of free carbide which did not go into solution with simple annealing after hammering to size. Etched with 10 per cent nitric acid and X 120.

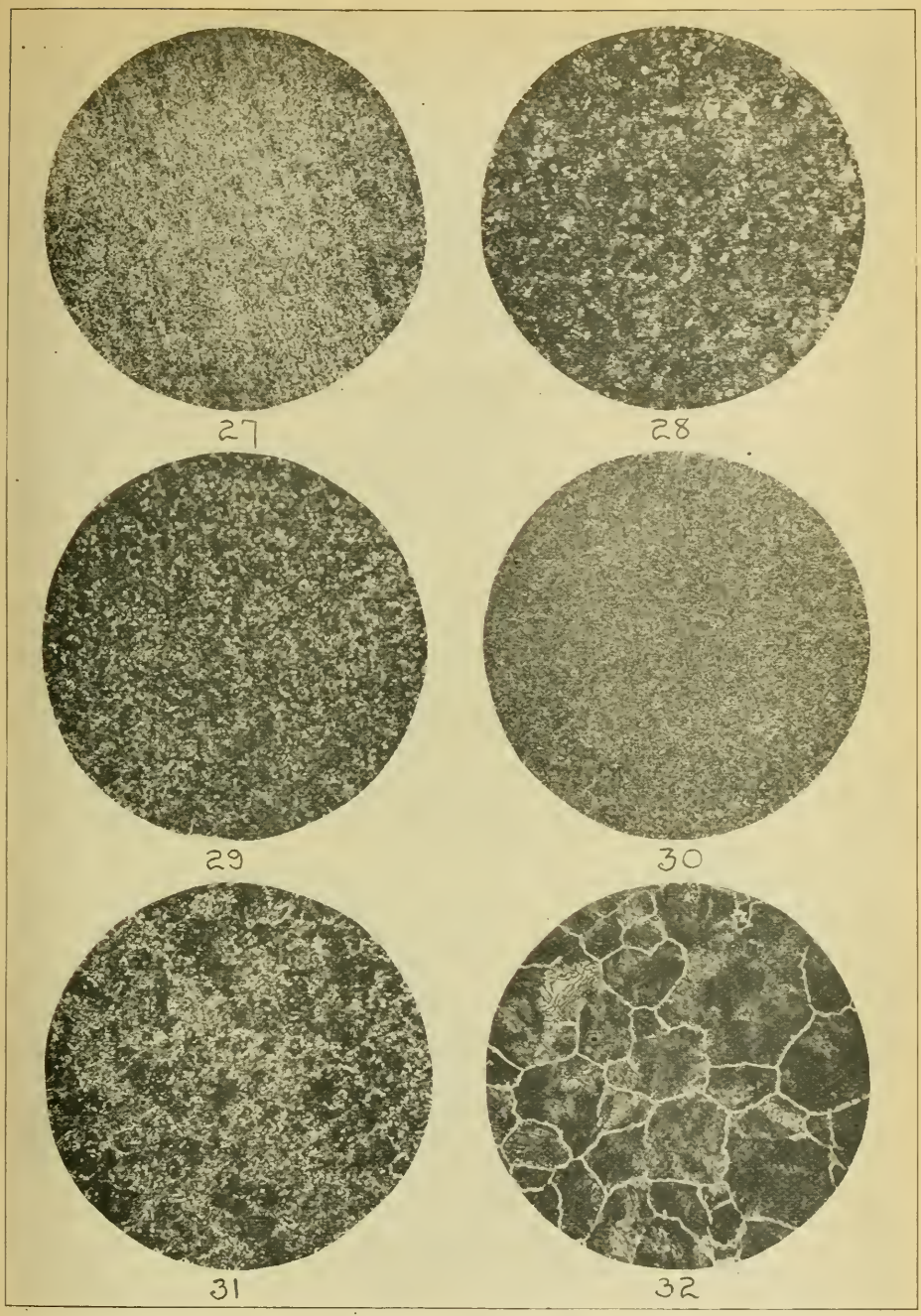


Fig. 27—Structure of same steel in Fig. 26 but which has been normalized at 1650 degrees Fahr. before annealing and hardening. Etched with 10 per cent nitric acid and X 120. Fig. 28—Structure of 1.30 per cent carbon, 1.60 per cent chromium tool steel which has been heated to 1800 degrees Fahr., slowly cooled to 1100 degrees Fahr., and then air cooled after hammering. Etched with 10 per cent nitric acid and X 120. Fig. 29—Structure of 1.30 per cent carbon, 1.60 per cent chromium tool steel heated to 1550 degrees Fahr. and cooled in furnace with door open. Etched with 10 per cent nitric acid and X 120. Fig. 30—Structure of 1.30 per cent, 1.60 per cent chromium tool steel after annealing at 1450 degrees Fahr., following treatments of Figs. 28 and 29. Etched with 10 per cent nitric acid and X 120. Fig. 31—Structure of 1.15 per cent carbon tool steel showing segregated cementite due to high temperature working. Etched with 10 per cent nitric acid and X 120. Fig. 32—Structure of 1.10 per cent carbon tool steel which has been finished at too high a temperature and annealed above the Ac range. A great grain growth shown. Etched with 10 per cent nitric acid and X 120.

shown was produced by annealing at 1450 degrees Fahr. after the previous treatments. The finishing of high carbon content steel at high temperatures sometimes causes the cementite to separate out in the form of longitudinal lines much the same as the ferrite of a low carbon steel forms bands when cold worked. Such a condition is shown in Fig. 31. Normalizing followed by annealing is necessary to correct such a condition.

It is sometimes the case that a steel which has been finished at too high a temperature is annealed at a temperature just over the Ac range for a long time and the grain growth is excessive. Such a condition is shown in Fig. 32. This represents a 1.10 per cent carbon tool steel which was annealed too long a time at 1400 degrees Fahr. after being finished at too high a temperature. Fig. 33 shows the same steel after being normalized at 1500 degrese Fahr. and then annealed at 1250 degrees Fahr. The cementite is completely broken up into small globules or spheroidized. A steel sent from the mill in the condition shown in Fig. 32 causes a great deal of trouble as it does not produce efficient tools. A hardened and tempered structure of the steel poorly treated is shown in micrograph Fig. 34 and easily proves why tools in that condition are practically useless.

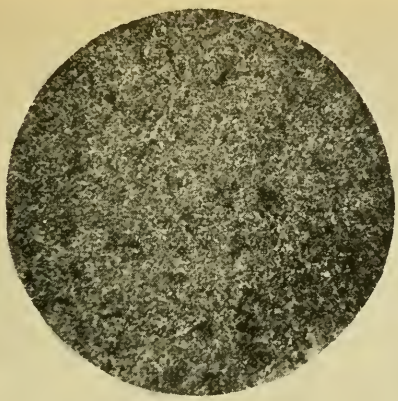
The correct structure for tool steels to be placed in the hands of the user has been found to be that in which complete spheroidization of the cementite has taken place. To obtain that structure it is necessary that the finishing temperatures of the steel be carefully regulated for the production of a sorbitic structure. Figs. 35 and 36 show the structures of 1.10 per cent carbon steel which has been annealed at 1350 degrees Fahr., a temperature just above the Ac range. It had been finished at too high a temperature in the rolling mill. Figs. 37 and 38 show the same steel after being heated to 1500 degrees Fahr. followed by air cooling and then annealed at 1250 degrees Fahr. and cooled in the furnace.

This article constitutes a plain statement of facts with sufficient illustrations to bring out some of the easily passed over, but fundamentally important phases of the manufacture of tool steels. The chief aim has been to present these illustrated facts without too much detail of equipment. The preparation of tool steel at the mill has been shown to embody the control of finishing temperatures, normalizing, annealing and the spheroidization of cementite, dependent upon the knowledge and use of the fundamental factors of steel treatment, namely time, temperature, mass, surface, and last but not least, the human element.

The steel mill has at least awakened to the necessity of producing tool steel that will cause the least trouble for the user and make the most efficient tools when properly handled by the steel treater, and it is hoped that the mechanical developments of the future, such as furnaces more economical in fuel consumption than many now used, and a better and more thorough understanding of the value and use of pyrometers and kindred apparatus will make the task easier to accomplish. Such a realization will constitute a marked step forward in the art of steel manufacture and treatment.

Discussion of Mr. Green's Paper

MR. SMALL: I would like to ask Mr. Green a question in refer-



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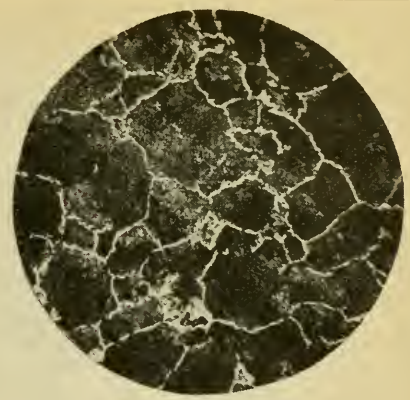

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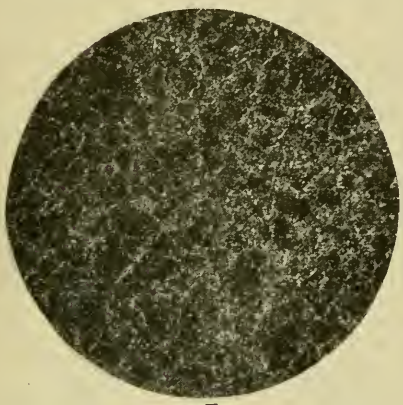

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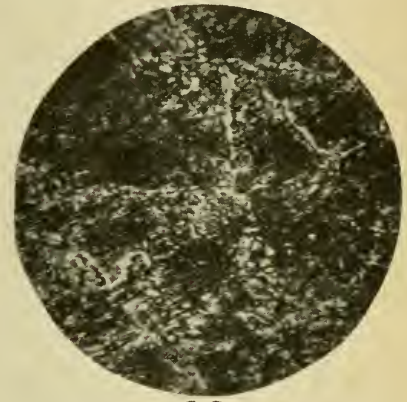

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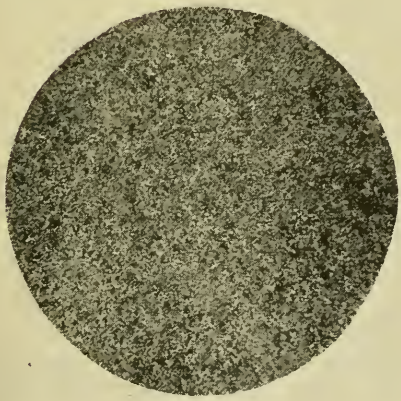

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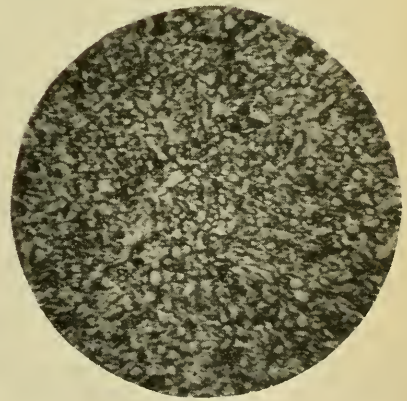

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Fig. 33—Structure of 1.10 per cent carbon tool steel shown in Fig. 32 but normalized at 1500 degrees Fahr. then annealed at 1250 degrees Fahr. Etched with 10 per cent nitric acid and X 120. Fig. 34—Structure of 1.10 per cent carbon tool steel shown in Fig. 32 hardened showing large grains which were not broken up by the hardening operation. Etched with 10 per cent nitric acid and X 120. Fig. 35—Structure of 1.10 per cent carbon tool steel which was annealed at 1350 degrees Fahr. after having been finished at too high a temperature in the rolling mill. Etched with 10 per cent nitric acid and X 120. Fig. 36—Same structure as in Fig. 35 but X 500. Etched in 10 per cent nitric acid. Fig. 37—Structure of 1.10 per cent carbon tool steel same as in Figs. 35 and 36 but normalized at 1500 degrees Fahr. and then annealed, showing spheroidized cementite. Etched with 10 per cent nitric acid and X 120. Fig. 38—Same structure as in Fig. 37 but X 500. Etched with 10 per cent nitric acid and X 500.

ence to the cementite segregation in those two pieces that broke. Do you contend that the breaking was along those lines of segregation?

MR. GREEN: It was in this particular case.

MR. SMALL: Do you think that would be true in other cases as well?

MR. GREEN: I see no reason why it shouldn't be. Cementite in straight carbon steels is the hardest and consequently the most brittle constituent, and if you divorce it and throw it out into certain well-defined lines, it is naturally a source of weakness in that particular tool. Now the tool that broke was a round die about 4½ or 5 inches in diameter, and probably 3½ inches thick, and it broke right across the section. The evidences were so plain that it followed those globular conditions that the microscope simply served to prove the point.

MR. MARSHALL: A hole, or a notch or a niche would aggravate that?

MR. GREEN: It was aggravated by a small center punch mark or a place punched for a drill for machining in the lathe.

MR. HOFFMAN: Did I understand you to say that proper forging temperatures for most grades of tool steels were 2100 to 2400 degrees Fahr.?

MR. GREEN: I said the temperatures in rolling were generally higher than in forging. I said the general rolling temperatures. But I don't think you will find tool steel is carried as high as 2400 degrees Fahr.

MR. HOFFMAN: What would you suggest as the proper rolling temperature?

MR. GREEN: It is impossible to suggest unless you know the analysis and size of material, speed of the mill and the number of passes that are to be given to the material.

MR. CROW: I would like to ask if you would, under any conditions, ever heat a tool steel to 2400 degrees Fahr.?

MR. GREEN: I think in that portion of the paper I tried to show that lower carbon steels were taken that high.

MR. D'ARCAMBAL: I noticed on the sample that you normalized and then annealed you always annealed at 1250 degrees Fahr. Why did you go lower than you would on a straight annealing?

MR. GREEN: That is hard to answer. To assure a proper tool steel leaving the mill with a structure that is acceptable to our customers for the work they desire to use it we have found that it is necessary to give them a cementitic condition where the cementite is entirely globular and to do that it is necessary to make a low temperature anneal. In those specimens that were normalized we normalized at 1500 degrees Fahr. to be sure that all cementite was thrown into solution at the high temperature before taking the lower anneal, although I have been able to successfully anneal steel in one operation, where the finishing temperature in the mill has been taken care of and the steel finished at approximately the Ar range, or slightly under.

MR. D'ARCAMBAL: The reason I asked that question was that we were furnishing some steel to one mill and they normalized it and claimed they re-annealed it from 1380 to 1400 degrees Fahr.

MR. GREEN: I don't believe that it is possible at 1380 and 1400 degrees Fahr. to give the steel to the customer in the globular cementitic condition. In fact, I think Dr. Sauveur has brought that matter out in his book, that low temperature annealing is a great help in producing the globular cementite.

MR. D'ARCAMBAL: How do you determine the proper high speed steel finishing temperature with hammering?

MR. GREEN: I haven't done any work with high speed steel.

MR. D'ARCAMBAL: One of the mills was telling me the other day they had some sort of magnetic system, but I didn't know just how magnetism with high speed steel acted.

MR. GREEN: I know nothing about it, and cannot answer your question.

HEAT TREATMENT OF STEEL FOR ORDNANCE PURPOSES

By H. F. Leary

DEVELOPMENT of the arts of metallurgy and metallography has been an important factor in the development of naval ordnance to its present high state of efficiency. The improvements in guns, armor and projectiles have been due largely to the steady development of the science of heat treatment.

It should be understood distinctly that heat treatment is an exact science, and is a means to an end, but that the most scientific heat treatment alone cannot accomplish desired results unless the material to be heat treated is of the proper quality. In other words, too often the heat treatment department has been called upon to doctor up and render satisfactory material improperly melted. In order that the science and results may be exact, the material, when turned over for treatment, must be homogeneous, free from impurities, and carefully melted. For example, if the aim is certain physical properties, these properties might be obtained by a standard thermal treatment in a homogeneous, pure carbon steel, whereas, if the melting methods are not modern and scientifically carried out, it might be necessary to use an alloy steel to obtain results as satisfactory. The necessity for quantity production with the consequent working of the melting plants to maximum capacity, has been detrimental to the development of the quality of production.

Another important point for consideration at the start is that we cannot expect to obtain the same results in large masses that we obtain on small specimens in a laboratory. That is, we cannot compare such results where there are mechanical treatments, or where thermal treatments involve a rapid cooling.

Failure to attain physical properties from a standard thermal treatment is not due alone to the melting, for the mechanical treatment or forging, and the preliminary annealing, or normalizing are also of the greatest importance. Not more than two decades ago, the thermocouple pyrometer was unknown in ordnance work. In the treatment of projectiles and gun forgings the eye of the heater was used, and on the skill of personnel depended the success in meeting physical requirements much as the success of the Damascus steel sword depended on the skill of the workmen.

When test bars showed unexpected failures, it was attributed to flaws or defects without any effort being made to know what these flaws were, or what caused them, and the forgings in question were treated or doctored up in order to meet the requirements. As the requirements of the specifications became more rigid, and as the arts of metallurgy and heat treatment developed, the science became more exact. Steps were taken to prevent grain growth after forging. Preliminary annealing was developed. Buttons were taken, and other metallographic examinations were made to determine whether the material was uniform and properly normalized before proceeding with thermal treatment. Couples were attached to the forging to be treated, and the temperature at various points on the forging recorded, rather than depending on the furnace temperature. Self-recording pyrometers were introduced. The effect of time of heating; holding the heat; the difference in quenching

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mediums; the time of immersing the steel; the time in the bath and the temperature of the bath, and of the piece when withdrawn, were all studied and recognized as of importance in obtaining the desired results. The theory of stress accumulation was considered, and the necessity for avoiding undue strains. The geometric condition of the forging was studied. The skin effect and the necessity of preliminary machining before quenching was also recognized.

The question of saving in weight has been a vital one, and a careful study has been necessary to determine the strength; the necessary factor of safety of a part; and how this required strength may be developed in as light a piece as possible. The torpedo is an example of the necessity of saving weight, where the mechanical design has developed a torpedo capable of running more than 5 miles at high speed. This would have been impossible had it not been practicable to build a steel air flask 10 feet long and 21 inches in diameter which would safely contain air compressed to more than 5000 pounds per square inch.

In general, the specifications covering ordnance material do not specify the heat treatment to be given. The physical and chemical requirements are specified in detail, and provided tests demonstrate the suitability of the material, it is considered satisfactory. However, there are certain general requirements regarding heat treatment which are incorporated in the specifications with the idea of insuring uniformity of the material and preventing injury through improper treatment.

These requirements include such specifications, as in the case of forgings, that they must be rough machined before treatment; that complete records of treatment must be kept; that in the case of castings, rapid cooling can be permitted only in certain cases specifically approved, and that they must be carefully annealed. In certain cases it is specified that quenching shall or shall not be permitted in the case of forgings, but it has not been the practice, as in some commercial specifications, to specify temperatures that shall be used.

The ordinary physical tests specified are tensile, bends, and in some cases Brinell and scleroscope. All these tests are static tests, and it would seem important to develop some form of dynamic test, inasmuch as the material is of a class which must withstand severe shock. The fact must not be overlooked that upon completion, the material is subjected to a ballistic test. The gun is proof fired at pressures greatly in excess of service pressure, the mount is proved, the torpedo is fired on trial runs, and the armor and projectiles are subject to ballistic test.

In all work in connection with gun mounts, it is essential that the castings shall be free from stresses, and of a composition and treatment which would exhibit shock resisting qualities. The fact that these castings are always rigidly inspected for blow holes and other flaws common to castings necessitates their being melted carefully, and this care tends to uniformity which renders them susceptible of responding to proper heat treatment. In the larger castings it has been necessary generally to use a nickel steel alloy in order to insure the physical requirements. Care must be taken both in inspection and manufacture to insure that the treatment is such that the entire casting will receive the heat, and that the piece is properly disposed in a furnace to effect this.

Gun yokes for even the largest caliber guns have been made of steel castings. In some of the earlier cases, fracture occurred on proof of the gun, and revealed an ingot structure even though successful tests had been made from coupons. This shows how little coupons can be

depended upon, unless the piece has been properly disposed in the furnace, and the treatment properly conducted by pyrometric control.

In general, coupons of ordnance castings must be attached to the body of the casting and not gated on. In small castings, it is more preferable where representative testing is resorted to, to cut up castings selected at random, taking tests from the body of these castings. Manufacturers desire to attach coupons so that they can be broken off readily in the foundry without the necessity of machining, but in this case the area of radiation on the coupon is much greater than the area through which the coupon can receive heat from the casting during cooling, so that the coupon will pass more rapidly through the critical range than the body of the casting, and therefore, in the majority of cases, gives false results on the physical tests. On large castings it would be a good practice to machine out test specimens wherever there is sufficient metal to insure that the treatment has been effective, unless the treatment has been properly supervised.

In the old days when guns were cast, their effectiveness was limited by the pressure that they would stand without bursting, and the only way to increase their strength was to increase the thickness of their walls. After a certain limit of thickness was reached, no increase of strength could be obtained. The built-up gun resulted.

The improvement in the effectiveness of our naval ordnance guns has kept pace with the development of the art of heat treatment by the introduction of alloy steels and careful heat treatment. We have been able in the past 20 years to increase considerably the physical requirements of the steel from which guns are built, and when the art developed so that enormous ingots could be cast successfully and homogeneous enough to be heat treated so that they met our requirements, it became possible to manufacture the largest possible caliber guns. It is doubtful whether a 16-inch 50-caliber gun could have been manufactured successfully under the specifications of 20 years ago, even though the ingots could have been cast of that size, and the mechanical equipment was available for the manufacture.

Specifications for gun forgings for the army and navy are alike, and are covered by a complete booklet. Numerous paragraphs are given regarding raw materials, discards, and size of ingots in order to insure that the material to be heat treated shall be of the best possible quality, and which, together with the requirements for heat treatment, will insure that a rigid treatment is not necessary to obtain the desired physical condition to pass satisfactory test.

No definite process is specified for the steel, but it is specified that the forgings shall be made of domestic steel manufactured from the best quality of raw material and by an approved process. Successful forgings generally have been manufactured of acid open-hearth steel, and it is believed that outside of the electric furnace, the best results are obtained by this process. The reason for this appears to be that the acid process gives the most homogeneous steel with greater freedom from oxides, segregation of the metalloids and other impurities.

Cases have been found where manufacturers endeavored to use ingots made by the basic process. Although the mechanical and heat treatment was such as would have insured success on an acid ingot, failure on physical test has resulted in one or more of the test specimens taken, and ultimately caused the manufacture to be made of acid

steel. In some cases alloy steel ingots were used, the ingots being similar to those from which satisfactory commercial forgings are made.

No requirements as to chemical composition are imposed, other than specified in maximum sulphur, phosphorous, and copper content. Certain forgings are made of what is defined as gun steel, which is a simple carbon steel. Where alloy steel is specified, a simple carbon steel is meant with such percentage of the alloy added as is necessary to obtain the required physical properties.

The physical properties specified vary from 86,000 pounds per square inch tensile strength, 46,000 pounds elastic, 18 per cent elongation, and 30 per cent reduction of area, to 95,000 pounds per square inch tensile strength, 65,000 pounds elastic limit, 18 per cent elongation, and 30 per cent reduction of area. While these properties are exceedingly easy to meet in small forgings, it is a difficult matter to manufacture and heat treat forgings of the largest size so as to exhibit these properties uniformly. The location and number of test specimens is such as to cover the area of the cross section of the forging, and to insure that the desired properties are obtained throughout the mass. It is of interest to note that in all cases of physical test, the elastic limit, or limit of proportionality, must be obtained by the use of a micrometer extensometer.

In the case of the largest forgings, four test specimens are taken at each end of the forging and are slotted out and so located as to cover the outer, middle and inner portion of the forging. In the case of failure of any of these test specimens, which are taken tangentially or transverse to the axis of the forging, a replace bar is laid out in wake of the failing bar and closer to the finish line, and the obligation is placed on the manufacturer to provide sufficient metal to cover all the necessary tests. To insure that the greatest care will be taken in the heat treatment of our gun forgings, it is required that the manufacturer shall assure himself by trial test specimens that the material is in proper condition before it is submitted, and the number of submissions is limited.

In rare cases, if the history of manufacture, treatment and test bars warrant, additional tests may be allowed, but in such cases a full number of bars are taken with such additional ones as are necessary to cover the location of all bars which have previously failed, and it is seldom that such a forging is ultimately accepted. Experience in testing has shown that the greatest percentage of failures is due to impurities in the nature of ghost lines and other segregations in the forging. This is indicated by an irregularity in the results of test specimens, and the fact that further treatment and test may result in the acceptance of the forging, is believed to be due to the decrease in the amount of these impurities from the end of the forging in getting closer to the finish line.

In locating test specimens, all prongs or extensions should be avoided and gone well back of, as these projections invariably present greater radiating surfaces, with a probability of being in a better condition of structure than the mass of the forging. There is in forgings of this nature a marked skin effect in treatment, and it is therefore specified that test bars shall be laid out so that their axis is a definite distance in from the surface which would prevent any effect on the physical properties. This effect has been noted to a marked extent in cases where it was endeavored to show that the structure was uniform throughout the mass by making metallographic examination at various points on the surface of the forging, and comparing the structure with the structure

found in the threads of test specimens. Little or no ferrite will be found in the grain boundaries close to the surface, whereas at a short distance inside the regular structure will be found. That the forgings are believed to be uniform when finished is due to the considerable machining after heat treatment.

The specifications for gun forgings require that as a preliminary treatment, forgings shall be annealed from a temperature above the upper critical, or Ac_3 point, after forging and before quenching. The precautions taken to prevent the rapid heating, and the length of time during which the forging is held at a treatment temperature, must be satisfactory to the inspector. Preliminary annealing may be conducted before rough machining. Every operation of heat treatment shall, if desired by him, be witnessed by the inspector, and if unsatisfactory in any way additional treatment may be ordered. The contractor shall keep records showing for each heat treatment:

(a) The time at which the forging was put in the furnace, and the furnace temperature.

(b) The time occupied in reaching the temperature required in the operation; the temperature so reached; and the length of time the forging is held at that temperature.

(c) The time at which the forging was taken from the furnace in annealing or drawing, and its temperature at that time.

(d) The elapsed time of immersion of both muzzle and breech end in the quenching medium; the quenching medium used, and the temperature of quenching medium before and after immersion.

The contractor is required to provide himself with self-recording pyrometers for measuring the temperatures actually used in heat treatment, and calibration is required. It is believed necessary on long forgings to keep a record of the temperature at various points, and the couples are placed in direct contact with the forging. Where differences in temperature are shown, they must be included in the records.

No annealing ever is permitted on any part of a forging, and the cooling is required to be uniform in a closed furnace and the forging not removed from the furnace until the temperature of the piece is below 600 degrees Fahr. All long forgings are required to be heated and quenched in a vertical position, and arrangement must be made to insure a flow of quenching medium through the bore. The last operation on every forging shall be a draw and should it be necessary to vary the temperature between the ends of the furnace, this variation must be uniform from end to end. Rigid requirements are deemed necessary regarding straightening of forgings.

Gun forgings are so designed as to have sufficient strength in the gun after assembly by shrinkage to withstand the highest proof pressures without any distortion. After the discard is made, the forgings must be so forged and mechanically treated that with a bored or punched ingot the walls are reduced at least 50 per cent. Similar requirements are specified for solid forgings, making an equivalent allowance for upsetting operations.

It is customary after forging to conduct a preliminary anneal and examination, to insure that a normal, uniform structure has been obtained. After rough machining, it should then be sufficient to obtain the desired condition by a simple quench and draw. If conditions have been such that this quench and draw leaves the metal too hard, as shown by trial test specimens, another draw would be given at a suffi-

ciently high temperature which experience would show to be necessary to obtain the desired results. If the forging is found to be too soft, it is necessary to quench it again at a higher temperature, or to quench at the same temperature and draw at a lower temperature than the previous draw. In such cases, all the test specimens taken should be uniformly high or low, or at least uniform as regarding those taken from one end. Where different physical properties are found at each end of the forging, the problem is somewhat more difficult and might involve the necessity of again normalizing the structure before a requench. In all cases, the breech end of the ingot is to be the breech end of the forging. The structure found in gun forgings generally is sorbitic with the grain boundaries plainly marked with uniformly distributed ferrite. In certain cases, needles of ferrite are found penetrating the sorbite grains in geometric form. This may be a persistence of the ferrite in the structure caused by the quench, and while this is not considered a desirable structure, it has not been shown by any test to be unsatisfactory.

Generally there is a considerable increase in the amount of ferrite in the boundaries in going toward the center of the forging, but this is seldom marked enough to cause a difference in the physical properties. While, of course, it would be desirable to develop some form of shock or fatigue test for gun forgings, the fact that the guns successfully pass the proof test and fire successfully at pressures greatly exceeding the service pressures, is believed to insure their suitability. Believing that a cold bending test could be adopted in addition to the tensile test requirements, experiments were conducted some time ago and it was found that in nearly all cases of successful forgings, 180 degree bends could be made flat successfully without fracture, showing that the metal was extremely tough. Successful bends were made about a radius on specimens that exhibited a ghost line structure. This ghost line structure has been a matter of great interest in gun forgings. The tensile physical test is a static test, and static tests, such as the tensile and bend, do not indicate that such structure is detrimental. A dynamic test would be a more suitable test to show its unsuitability, and it is believed that such tests have been made and show conclusively that such a condition is an inferior one.

Where streaks of ghost lines are found in the forging, they generally are surrounded by good metal, and the factor of safety is so large that in the case of most large forgings, they were not believed to be detrimental. Where ghost lines are found on the surface, they are examined metallographically and their extent can be noted by making a metallographic examination of the forging at the end where they appear simply as dots. Many rejections, however, have resulted from this cause, because such flaws are considered evidence of the doubtful value of a forging.

The ghost lines or streaks in large forgings are interesting as they depend somewhat upon the method of manufacture of the steel. They are of two general classes: First, with fine grain and a ferrite predomination; and second, with large grain and absence of ferrite. Inclusions predominate through the streaks, often of a size visible to the eye without magnification. These inclusions generally are believed to be manganese sulphide and silicate and where segregated have always been regarded with suspicion. Later development tends to the belief that the most dangerous element in the steel is the oxide, which appears only as specks under high magnification, but which settles in the ferrite bound-

aries and weaken the adhesion. It is to the electric furnace that we must look for improvement in this respect.

In the early days, projectiles were made of cast steel and later they were forged. Still later, it was found that by reheating them after forging, an increase in the effectiveness was produced, and when the necessity for penetration of armor developed, the points were chilled in the beginning by casting the point in a chilled mold. Later, as heat treatment was studied and introduced, coupled with the introduction of alloy steel, the projectile passed armor in effectiveness.

With the development of the cap for projectiles, the point could be made still harder without breaking off, so it has been a race constantly between armor and projectiles, and with each new development in one, developments and improvements have resulted in the other. The development in the art of heat treatment primarily brought about this competition and improvement.

Armor-piercing projectiles are generally manufactured by the acid open-hearth, or electric furnace. The shape of the ingot varies with the manufacture, as well as the forging methods. The melting is given the greatest care. It is believed that the first really successful armor plate projectiles were made by the crucible process. They are made of alloy steel with various hardening elements added. The greatest care must be given in melting, and in the heating and the forging operation, care being taken to prevent the formation of a core, and to insure that the metal is worked throughout its mass. This forging operation must be carried on to as low a temperature as possible to prevent grain growth. Following forging, the projectiles are given a preliminary anneal and steps are taken to insure that they are normalized. They are then rough machined nearly to size and given a series of quenchings in oil with drawing operations following for the purpose of refining the grain structure and obtaining a quality known as fiber.

The operation of heat treating the forward end of projectiles for hardness is one of great refinement, and one which is held secret by the various manufacturers. It is accomplished by a graduated heating beginning with the point, followed by a complete quench in agitated cold water. This puts the entire projectile in exceedingly hard condition. The heating for this treatment is accomplished generally in a bath of molten lead to insure accurate control of both temperature and position and application of the heat. After this, the base of the projectile is heated to a lower temperature than was used for quenching, and upon withdrawal from the bath or furnace, is suspended nose down and immersed in agitated cold water, which draws or tempers the rear portion while preserving the hardness in the head. The point of the projectile is covered by a cap, which is annealed and fibered. The cross section of a projectile ingot, as well as the cross section of a finished projectile, which has been split open, presents as fine a structure as could be found in any class of steel.

When armor was first made, it was of wrought iron, and the only way of obtaining increased resistance to attack was by increasing the thickness. In some cases, armor was made 2 feet or more in thickness, and the weights were so enormous that relatively small protective area could be given a ship, but even then the crude old fashioned chilled-point projectiles found their way through this armor at the existing battle ranges. There then was developed compound armor which consisted of a bessemer steel plate on a wrought iron back, and some thought was

given to treatment. Later on, the development of face-hardened armor, placed armor ahead of the projectiles and greatly decreased the necessary thickness of armor, permitting much greater areas to be protected on ships. As the development of treatment of armor progressed, coupled with the introduction of alloy steel and toughening and hardening elements, the thickness further decreased, and the saving of weight thereby allowed the introduction and improvement of other offensive and defensive elements entering into the construction of a ship of war.

The heat treatment of armor is of great interest because the modern armor plate probably calls for the largest size ingot, and is probably the greatest mass of steel heat treated to high properties. It is to be regretted that the present processes are by necessity of a confidential nature, as the matter of their mechanical and heat treatment is most interesting. The process generally used is a modification of the Krupp process. When it is considered that casting alloy steel ingots weighing 400,000 pounds is the first step in this process, it can be appreciated with what tremendous difficulties the armor maker is confronted, especially when it is considered that upon the completion of a quantity of about 500 tons of armor, representing twenty or more plates, the acceptance of this group of armor depends upon the successful ballistic test made upon one of these plates selected at random.

A typical analysis of a modern Krupp cement plate is as follows: Carbon 0.35; nickel 3.90; chromium 2.0; manganese 0.35; silicon 0.07; phosphorus 0.025; and sulphur 0.020 per cent. The ingots are made of basic open-hearth steel. The ingot is stripped while still hot, cleaned and charged in a furnace to be brought to a forging heat, in order to save as much of this great amount of heat as possible. It is probable that the center of the ingot is still plastic when the outsides are below color, and in the furnace the heat is uniformly distributed before the forging operation. The ingot is then forged under a powerful hydraulic press to within about 15 per cent of its final thickness, and the discards taken. The plate must then be annealed to eliminate forging strains and to endeavor to normalize the structure. As in the case of the projectile, various treatments follow to insure the desired grain refinement. The ingots are then placed in carbonizing furnaces, and the surfaces super-carbonized to the desired amount, after which the plates are reforged to the desired final thickness. After this operation an annealing process is necessary to prevent cracking while cooling. The face of the plate must be specially heated and chilled under a spray in order that finally the surface of the plate shall be hard and the back tough. The condition of the plates are inspected by drilling to find the depth of the chill, by hardness tests, by fracture tests, and by physical tests.

In conclusion, it can be said that modern ordnance requires the application of the art of heat treatment to the fullest extent in order to attain the results desired in its armor, projectiles and guns, and skill and knowledge of the art is necessary in the manufacture of all the component parts of the innumerable mechanisms demanded by other branches of ordnance. As heat treatment progresses so will ordnance continue to develop as in the past.

EFFICIENCY OF DIFFERENT MIXTURES FOR CYANIDE HARDENING AND THE ROLE OF NITROGEN IN THE PROCESS

By Victor E. Hillman

ACCORDING to present day usage, the term cyanide hardening implies that the steel is immersed in a bath of molten sodium cyanide, allowed to remain therein until sufficient carbon has been absorbed to effect surface hardness, and then subsequently quenched in either oil or water. The aforementioned thermal and chemical treatment produces a skin hardness that will resist abrasive action to a remarkable degree.

The process has its limitations and its own particular sphere of usefulness. Notwithstanding, it has found extensive application where depth of case is not a prime requisite. To the lay mind, cyanide hardening implies that potassium cyanide is used. In recent years, however, sodium cyanide has been substituted with marked success, due to the fact that sodium and potassium belong to the same family, and possess similar properties in combination with the cyanogen radical.

Sodium cyanide has a cyanogen content of 51 to 52 per cent, whereas, the potassium salt contains approximately 38 per cent cyanogen. The carburizing action of liquid cements is generally attributed to the presence of the cyanogen radical. Therefore, the value of the sodium compound is apparent.

Sodium cyanide is used in varying degrees of concentration for carburizing purposes. Ninety-eight per cent sodium cyanide is very efficacious as a fusible carburizing medium and the same is true of a standard mixture containing 76 per cent sodium cyanide and the balance sodium chloride. Other admixtures have been placed on the market containing sodium cyanide, sodium chloride, and sodium carbonate. The chloride and carbonate are inert, and do not contribute in any way to the carburizing action of the bath, but their presence increases the melting point of the compound, and thereby renders it better adapted for the purpose designed. Therefore, this paper will deal with three distinct classes of cyanide hardening mixtures, namely: 98 per cent sodium cyanide, 76 per cent sodium cyanide, and 27 per cent sodium cyanide.

The performance of a cyanide compound containing an admixture of 27 per cent sodium cyanide, 16.8 per cent sodium chloride, and 54.5 per cent sodium carbonate was observed under actual working conditions for a period of three years. Certain operating difficulties were in evidence from time to time, although they proved to be of little or no consequence.

Just before the compound reaches the desired temperatures, 1475 degrees Fahr., a black viscid coating forms on the surface of the liquid. Further heating, however, produces a clear molten bath free from floating scum. The black charred mass which arises to the surface of the liquid is unquestionably an admixture of graphite and sodium carbonate and this salt manifests a tendency to separate from the remaining ingredients at a low temperature. The blackening of the carbonate is occasioned by the presence of graphitic particles which are liberated from the cast iron container. If an attempt is made to operate the bath at 1300 degrees Fahr. or thereabouts, a scum will also be in evidence.

The presence of sodium chloride (common salt) and sodium car-

A paper presented at the Indianapolis Convention. The author, Victor E. Hillman, is metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

bonate (washing soda) exert no carburizing action whatever. They are incorporated with sodium cyanide for four reasons: 1. To cheapen the product; 2, to raise the melting point; 3, to act as "fixitives" which prevent excessive volatilization of the fleeting cyanogen base; and 4, to assist in the decomposition of the sodium cyanide thereby rendering the $(CN)_2$ group more readily available as a carburizing agent. The depth of penetration incident to the use of the subject mixture was determined by keeping the temperature of the bath constant at 1475 degrees Fahr., and varying the length of time that the specimens were allowed to remain in the liquid cement.

Forty-eight pieces of steel 5/16-inch square and 1-inch long were immersed in the molten compound and duplicate sets of specimens were withdrawn and quenched in water at 5-minute intervals up to the first hour, and every 10 minutes after that. The duration of the entire test consumed exactly three hours. Admittedly, the three-hour period is of no practical value, although it is instructive to observe the effect of the prolonged carburizing treatment.

Material of the following analysis was used for determining the depth of penetration: Carbon 0.15; manganese 0.50; sulphur 0.09; and phosphorus 0.12 per cent. Commercially this steel is known as screw stock. It has low carbon, and high sulphur and phosphorus. The steel is used for its free-cutting qualities when smoothness of finish and high production are required. The majority of articles which are cyanide hardened are made from this grade of steel on the automatic screw machines, hence, the reason for its selection for test purposes.

The case is composed of two distinct fields, namely, a martensitic outer zone, and an inner troosto-sorbite area of lesser carbon content. The depth of case is ascertained by measuring the distance from the outer edge of the specimen to the center of the second zone. In passing it may be of interest to mention that the etched microstructure of the case possesses a yellowish tinge in contradistinction to the jet black appearance of the zones produced by solid cements. The specimens were polished and subsequently etched in a 5 per cent solution of nital. Measurements were taken with the aid of an eyepiece micrometer, which was standardized against a scale of known calibration.

Curve *A*, Fig. 1, illustrates the depth of case penetration obtained by subjecting low carbon 0.15 per cent steel to the carburizing and nitrogenizing action of a 27 per cent cyanide mixture. Note that there is a gradual development of the case during the first hour of immersion. Subsequent penetration is retarded, however, in view of the fact that the shell after becoming saturated, prevents the ingress of additional carbon and nitrogen. After the first hour, the curve gradually slopes toward the horizontal until the completion of the test.

Inasmuch as the immersion period for commercial cyanide hardening generally is 30 and seldom exceeds 60 minutes, the discussion of the curve will be confined to the one-hour period. When steel is cyanided for 30 minutes in a 27 per cent mixture at a temperature of 1475 degrees Fahr., the depth of penetration amounts to approximately 0.04 inch; whereas, the width of the case is proportionately less when the time factor is reduced.

On the other hand, one-hour immersion produces a layer nearly equivalent to a depth of 0.07 inch. It should be borne in mind that the size of

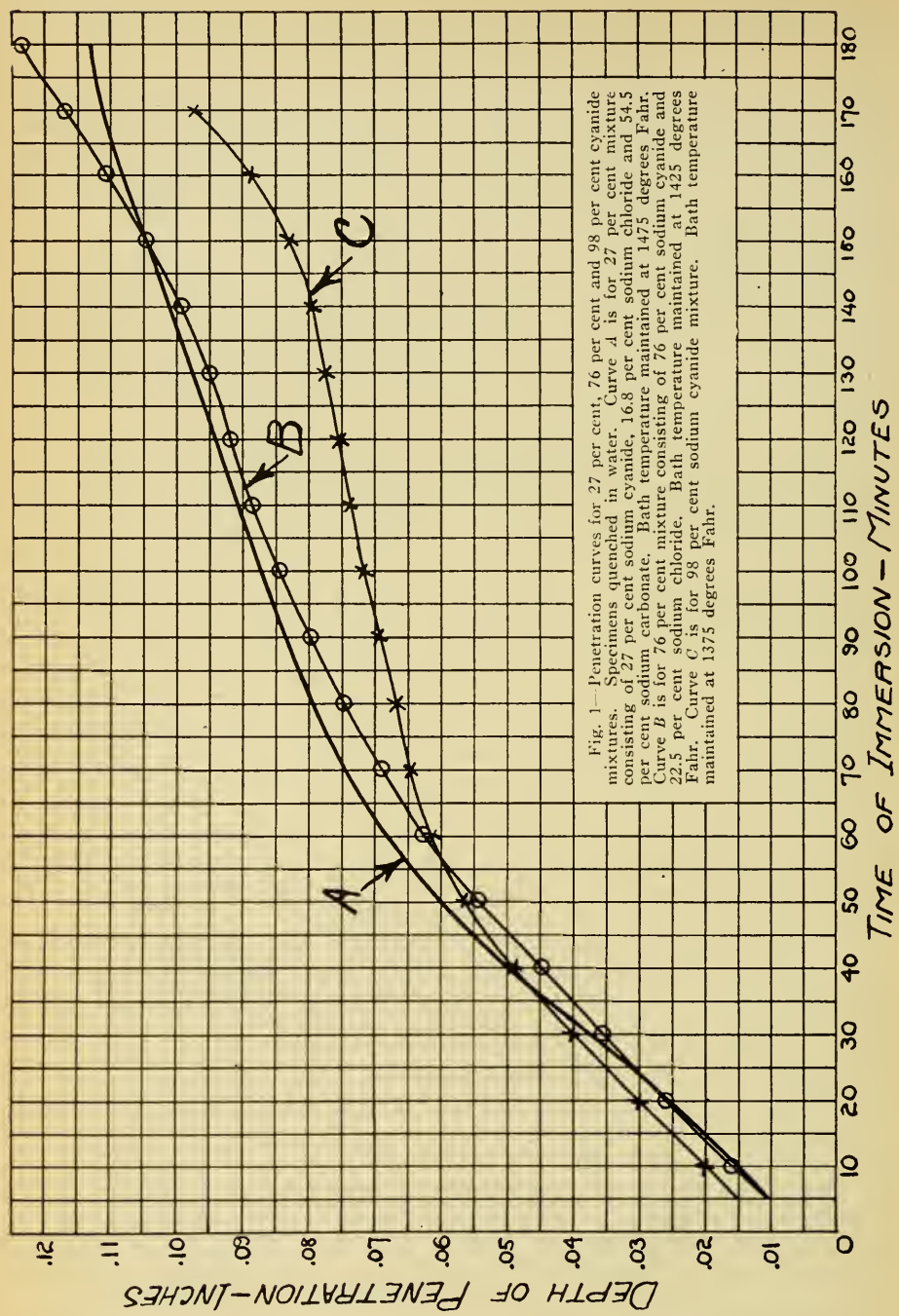

Fig. 1—Penetration curves for 27 per cent, 76 per cent and 98 per cent cyanide mixtures. Specimens quenched in water. Curve *A* is for 27 per cent mixture consisting of 27 per cent sodium cyanide, 16.8 per cent sodium chloride and 54.5 per cent sodium carbonate. Bath temperature maintained at 1475 degrees Fahr. Curve *B* is for 76 per cent mixture consisting of 76 per cent sodium cyanide and 22.5 per cent sodium chloride. Bath temperature maintained at 1425 degrees Fahr. Curve *C* is for 98 per cent sodium cyanide mixture. Bath temperature maintained at 1375 degrees Fahr.

the part which is being treated has a direct bearing upon the time factor of immersion. Penetration commences from the moment that the steel passes its lower critical range. Therefore, due allowance should be made for the period which is required to bring the article to the absorption temperature. The mixture mentioned previously should find extensive use in the production of a superficial case such as is required on articles subject to light wear. Moreover, the compound serves as an excellent heating medium.

The fumes which arise from the 27 per cent mixture are not dangerous, although they are decidedly obnoxious inasmuch as they irritate the mucous membrane in the nasal passages and thereby produce violent sneezing. The lachrymal glands also appear to be affected, in view of the fact that a copious discharge of watery fluid passes from the eyes and nose of workmen who are unnecessarily exposed. The fumes consist mainly of sodium carbonate, sodium cyanate, alkali chlorides, and a small amount of cyanide.

If hoods are installed over the cyanide furnaces and connected to suitable fans, the fume nuisance is abated. Good ventilation is of prime importance also. A prominent medical authority says, "Broadly speaking, constant exposure to any chemical compound is likely to be injurious to health particularly if it is likely to give rise to dust, fumes or gas," and. . . ."an abundant supply of fresh air is the best method of protecting the health of the worker."

The carburizing action of a compound containing 76 per cent sodium cyanide and 22.5 per cent sodium chloride was determined by precisely the same procedure followed in the previous tests, save for the temperature of the bath. It is not feasible to operate the 76 per cent mixture at a temperature in excess of 1425 degrees Fahr. due to excessive volatilization, of the cyanogen base.

Curve *B,* Fig. 1, illustrates the effectiveness of the subject matter. As in curve *B* there is a gradual development of the case for the first hour of immersion, after which the velocity of penetration is somewhat retarded. Moreover, the 30 minute and 60-minute specimens yield measurements which are nearly identical with the results obtained from the 27 per cent mixture. It appears that the higher concentration of the cyanogen radical does not in any way contribute toward the efficacy of carburization. This is occasioned, first, by the necessity of operating the 76 per cent bath at a lower temperature and second, by the fact that the cyanogen content of the 27 per mixture is more than ample to satisfy the saturation point of the metallic charge. There is no doubt, however, but that the 27 per cent compound will have to be replenished oftener. It is a well recognized fact that fusible cyanides become impoverished by continual use.

Curve *C,* Fig. 1, is representative of the carburizing action of commercial sodium cyanide. Inasmuch as the melting point of this mixture is 1004 degrees Fahr., it is mandatory to confine the operation of the bath to a temperature of approximately 1375 degrees Fahr. There is no particular advantage incident to the use of the more expensive compound. It may be noted that for the first hour, the curve practically parallels the slopes obtained from the 27 per cent and 76 per cent mixtures. As the period of immersion is increased, the velocity of penetration is retarded. This may be due in a measure to the increased con-

centration of the carbon in the cemented zones which manifest a tendency to become saturated and thus to prevent the influx of additional carbon.

The size of the pot appears to have a marked influence upon its longevity. Small containers, 6 inches wide, 20 inches long, and 6 inches deep and having ½-inch walls, are serviceable for six to nine months, whereas, the larger pots, 13 inches wide, 25 inches long, and 12 inches deep having ¾-inch walls, have an average life of 21 days. If the pots are suitably reinforced and properly supported, their replacement is not an expensive proposition. Cast iron pots will resist the action of the molten cyanide for a reasonable length of time, providing they are sound, free from blow holes, porosity, and shrinkage flaws.

The writer holds a firm conviction that the life of a cyanide container is a function primarily of molding and casting practice. Various high temperature alloys have been tried and rejected inasmuch as the benefits derived were not commensurate with the increased cost. A gray iron pot, 13 inches wide, 25 inches long, 12 inches deep, and having ¾-inch walls, costs approximately $30 as against $346.25 for a container cast from a special alloy mixture. In certain instances, the high priced receptacles failed after one week's service due to faulty casting practice.

The molten cyanide solution is operated intermittently, that is, the bath is brought to a temperature of 1375-1475 degrees Fahr. and kept at this degree of heat for seven hours, and then it is allowed to cool for the night. Cast iron will withstand the heating and cooling effect of the bath to better advantage than the special alloys.

Alloy containers have a tendency to develop cracks while cast iron fails because of excessive bulging. Moreover, cast iron pots suffer more from the corrosive action of the cyanide than high temperature alloys. In passing, it will shorten the life of any pot. An effort should be made to obtain a neutral atmosphere in the combustion chamber of the furnace, for the cutting action of a highly oxidizing flame is well known.

It is customary to determine the effectiveness of cyanide hardening by resorting to the file test. If the metal has responded to the case hardening treatment, the peripheral layer cannot be attacked with a file. The depth of the carburized surface, however, can be ascertained only by means of microscopic examination.

Brinell and scleroscope values do not give a satisfactory index to the efficiency of cyanide hardened metals for when a specimen is subjected to the Brinell test, circumjacent cracks appear in the vicinity of the depression. The readings obtained are more or less variable, this being due probably to the difficulty which is experienced in reading the diameter of the indentation. The scleroscope, in a measure, is more reliable than the Brinell machine for testing hardened surfaces. The height of the hammer rebound yields fairly concordant results, although there is no appreciable difference between specimens cyanided 5 minutes and 65 minutes.

The mechanism of cyanide hardening has been the subject of considerable controversy. Undoubtedly, the cyanogen radical exerts a nitrogenizing and carburizing influence on the metal. Nitrogen needles were noted in the microstructure of a specimen of low carbon steel that had been subjected to the influence of ammonia, for 100 hours at 1400 degrees Fahr. The presence of similar needles, their length, and orientation was duplicated by immersing a low carbon steel in a 27 per cent cyanide

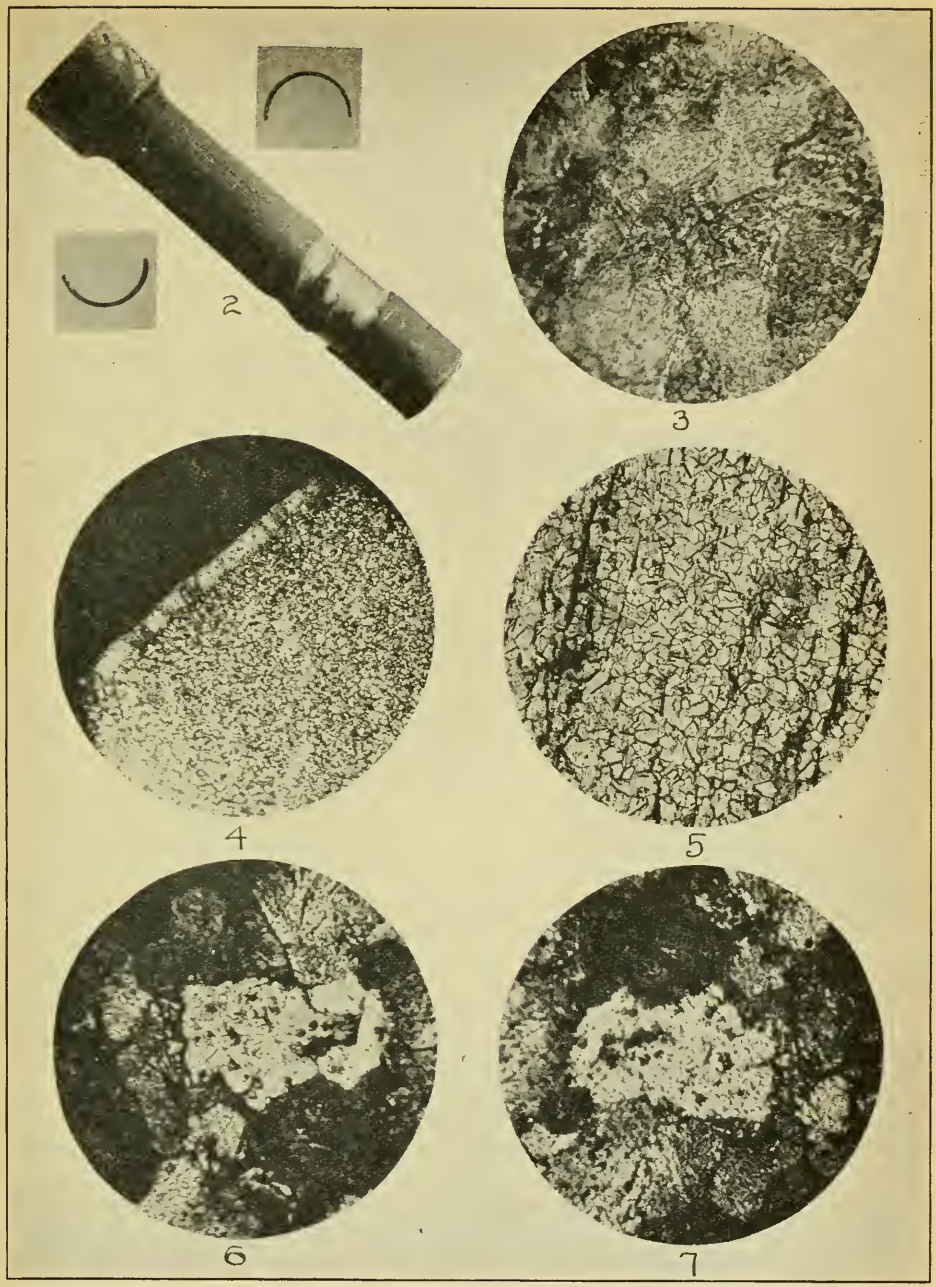

Fig. 2—Specimen treated with ammonia for 100 hours at 1400 degrees Fahr., illustrating power of nitrogen to form a layer possessing similar characteristics to case formed in cyanide hardened steel. Fig. 3—Specimen subjected to influence of cyanogen radical for 32 hours at temperature of 1450 degrees Fahr. and cooled slowly. Note sinuous flakes in center. A similar pattern is obtained in specimens that have been nitrogenized. This irresolvable structure has been designated "flavite." Specimen etched and X 425. Fig. 4—Micrograph showing the appearance of the case, which is 0.054 inches deep. Carburized 45 minutes in 27 per cent mixture at 1475 degrees Fahr. Specimen etched and X 100. Fig 5—Specimen showing micro-appearance of iron nitrogenized 100 hours at 1300 degrees Fahr. Note Fe_2N needles. Specimen etched and X 100. Fig. 6—Specimen cyanided 32 hours at 1425 degrees Fahr. Note irresolvable pearlite or "flavite." The Fe_2N needles are plainly discernible in the ferrite areas. Specimen etched and X 425. Fig. 7—Specimen cyanided 32 hours at 1450 degrees Fahr. Note irresolvable pearlite or "flavite." Specimen etched and X 425.

bath for 32 hours at a temperature of 1450 degrees Fahr. Hence by a process of elimination, it is reasonable to infer that cyanide hardened articles are nitrogenized.

A specimen that was treated with ammonia is shown in Fig. 2. Broken ringlets may be noted, these being part of the case that was formed. Nascent nitrogen possesses the property of forming a layer which is hard and brittle. The cyanogen radical also produces a case that is hard, brittle, and interspersed with nitride needles. Nitrogen is the only element that is common to both treatments, hence, the natural inference that the influence of nitrogen contributes toward the formation ot the case, and the physical properties imparted.

Table I

Operating Data for Cyanide Hardening Tests

MELTING POINT TABLE

	Melting temperature Degrees Fahr.
Sodium Chloride	1472
Sodium Cyanide	1004
Sodium Carbonate	1562

CRITICAL TEMPERATURES OF STEEL USED

	Degrees Fahr.
AR_1	1283
AR_2	1409
AR_3	1562

COST OF MIXTURES

27 per cent mixture	$0.20 per pound
76 per cent mixture	0.25 per pound
98 per cent mixture	0.30 per pound

A number of the cyanide hardened specimens were treated individually with hot hydrochloric acid. The solvent action of the acid was allowed to continue until the case was dissolved and the solution was then made alkaline by the addition of sodium hydroxide and subjected to distillation. The distillate when tested with Nessler's reagent yielded a voluminous brown precipitate (OHg_2 INH_2I), thus the presence of a large amount of nitrogen in the case was definitely established. The nitrogen evidently exists in the case as a nitride (Fe_2N) which is converted to ammonium chloride by the action of the acid, and retained as such until the (NH_3) radical is expelled through the agency of distillation.

Steel specimens in the natural state, that is, not cyanided, were subjected to this analytical procedure and when the distillate was treated with Nessler's Reagent, only a faint yellow color was discernible. No precipitate whatever was in evidence.

The micro-appearance of the unhardened case possesses certain peculiarities. Under low magnification the field resembles pearlite, but differing from that microconstituent in that the dark areas are devoid of laminations when viewed through high power lenses. The same condition is true after the specimens are normalized.

As a matter of convenience this irresolvable micro-constituent has been designated by J. Kirner as "flavite." It is a sinuous mass rich in

nitrogen, responsive to various etching reagents, carbon bearing, and present in articles that are cyanide hardened. Various investigators have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.30 to 0.60 per cent. A specimen is shown in Fig. 3.

In Table I are shown some of the operating data used in conducting the series of experiments. After extensive investigation the following conclusions regarding cyanide hardening may be drawn:

1. Cyanide hardening is poorly adapted for the production of deep cementation.

2. The depth of penetration increases with the time of immersion.

3. The 27 per cent compound parallels the effectiveness of the 76 per cent and 98 per cent mixtures.

4. It is desirable to incorporate fillers with the sodium cyanide to raise the melting point of the mixture.

5. Cyanogen exerts a carburizing influence while the iron is in the alpha and beta state, that is, from 1375 to 1475 degrees Fahr.

6. The case contains an abundance of nitrogen.

7. Nitrogen possesses the power of forming a microconstituent known as "flavite."

Discussion of Mr. Hillman's Paper

MR. HILLMAN: Prior to making these tests I was under the impression that the depth of cyanide hardening would not increase after half an hour. Many foremen entertain the idea that maximum penetration is obtained after a half hour immersion and any increase in time which the metal is allowed to remain in the carbonizing bath has no influence whatever. I find that to be incorrect.

MR. McCLOUD: I would like to call the attention of the speaker to the fact that it is possible to so combine the sodium carbonate and sodium chloride that you obtain an eutectic mixture which will have a melting point scarcely above that of sodium cyanide, if you used sodium chloride and sodium carbonate in the proportions of 65 per cent carbonate and 35 per cent chloride. I believe that is a close mixture to the eutectic mixture with a melting point of about 1100 degrees Fahr. I would also like to point out, as the speaker has not noted it, the rapid decomposition of sodium cyanide in the pots. I don't know whether Mr. Hillman has had occasion to make any analysis of the baths after they have been in use for a short time, but I know when I first made some determinations of the cyanide and carbonate present in sodium cyanide pots, I was much surprised with the speed of the decomposition. If you start with 76 per cent cyanide, within a few hours it has dropped off and inside of about five hours you don't have 10 per cent of sodium cyanide present in the bath. I think that factor should be considered in explaining the bending of the curve and the falling off in the penetration. Undoubtedly, the explanation that Mr. Hillman has made of the saturation is a factor but I believe my explanation has some bearing.

MR. HILLMAN: Mr. McCloud's remarks have a direct bearing on the case. My experience with the decomposition of the bath has been in accordance with Mr. McCloud's remarks, namely, that you must renew

the bath or your carborizing will become ineffective, if you attempt to operate the same bath over too long a period. Insofar as a layering was concerned, I was under the impression that the various compounds, the chloride, carbonate and cyanide would form three distinct layers when the bath was heated, but that does not seem to be true, because the boiling, or ebullition of the bath, seems to incorporate thoroughly the three compounds into one. At what temperature did you operate?

MR. McCLOUD: I should have stated that my operation was at a somewhat higher temperature, about 1500 degrees Fahr. I also intended to bring out the fact that even 1400 and 1475 degrees Fahr. is a rather low temperature for the treatment of a 0.15 per cent carbon steel, and I believe that even in the production of parts for superficial hardness, these generally being of small size, it is just as well to operate at a temperature where you get a little benefit from the heat treatment.

MR. HILLMAN: The only reason I did not operate at a higher temperature is that the bath is decomposed readily, in fact, the pure salt cannot be operated at a higher temperature. I operate under practical working conditions. These baths have been in operation for three years. Several tons of work have been turned out. It is strictly a production proposition. The only theory I have imparted was contained in the last part of the paper, on the nitrogen and "flavite," which was my only way of explaining the results I found, and of course, they are open to criticism.

MR. BROPHY: You believe that carbon is present in "flavite"?

MR. HILLMAN: Yes.

MR. BROPHY: We have conducted research in the laboratories of the General Electric Co., using pure ammonia. We obtained the dark areas containing no carbon at all—no chance to contaminate the ammonia.

MR. HILLMAN: That is a contribution to the paper. If there is no carbon there that merely substantiates my other statement that nitrogen is the cause of your case. Is that true?

MR. BROPHY: Yes. How much carbon did you find in the case?

MR. HILLMAN: I did not make an analysis.

MR. BROPHY: We found 0.30 per cent. That is not sufficient to account for it.

MR. HILLMAN: I stated in my paper that the carbon varied from 0.30 to 0.60 per cent.

MR. BROPHY: We never found it as high as 0.60 per cent.

FATIGUE OF METALS UNDER REPEATED STRESS

By H. F. Moore and J. B. Kommers

PROGRESSIVE failure or fatigue of steel and other metals under oft repeated stress, is of great interest to designers and users of high speed machinery. Fatigue of structural members has been discussed at various times, but it seems probable that, with the exception of reversed stress members in busy bridges and viaducts, structural parts are in little danger of fatigue failure.

The general problem set for the first stage of the joint investigation was to find out by a series of long time reversed stress tests of various kinds of steel together with careful static tests of the same steels, what relation exists between the static elastic strength of steel and its ability to withstand millions of reversals of stress. A secondary problem was to try various tests commonly used on steel to see whether any of these tests give indications of the ability of steel to withstand oft-repeated stress.

It was decided to continue the scope of this preliminary investigation to ferrous materials, and to choose a series of materials which should be distributed widely among the varieties of steel that are in common use. Table I gives the chemical analyses and reference numbers for the steels tested. It was decided to give as many of the steels as possible at least two different heat treatments. The heat treatments used are given in Table II. It is believed that this series of materials comprises a more complete reconnoissance of the field of ferrous metals than has been attempted in any previous series of repeated stress tests.

Reversed stress tests were the principal series of tests and were supplemented by tests in tension, compression, and torsion. Brinell and scleroscope hardness tests, impact bending and impact tension tests, repeated tests and magnetic tests for homogeneity. The rotating beam type of testing machine was chosen for the basic series of reversed stress tests. This machine is shown in Fig. 1. The machine produces a uniform bending moment on the specimen between the bearings *C* and *D*. This type of machine has been used by many investigators, and the present machine was patterned after that described by F. M. Farmer before the 1919 meeting of the American Society for Testing Materials. Other reversed stress tests were made in bending on an Upton-Lewis machine and in torsion on a Olsen-Foster machine.

For the static tests a 100,000 pound Riehle testing machine was used, for the impact tests a Charpy machine, and for the repeated impact tests a machine constructed at the laboratory was employed. A Ewing extensometer was used for strain measurements in the tension and compression tests, and a detrusion indicator employing an Ames dial was used in the torsion tests.

In the rotating beam specimen it was found necessary to reduce the diameter of the specimen at the middle of its length in order that it should

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From a progress report of the Joint Investigation of the Fatigue of Metals. It is an abstract of Bulletin No. 124 issued Dec. 1 by the Engineering Experiment Station, University of Illinois, Urbana, Ill. The Joint Investigation of the Fatigue of Metals is conducted under the auspices of the National Research Council, the Engineering Foundation, the General Electric Co., and the Engineering Experiment Station of the University of Illinois. Of the authors, H. F. Moore is research professor of engineering materials, University of Illinois and in charge of the investigation and J. B. Kommers is research associate professor of engineering materials, University of Illinois, and engineer of tests of the investigation. The illustrations and tables used in this article are loaned to TRANSACTIONS through the courtesy of *The Iron Trade Review*.

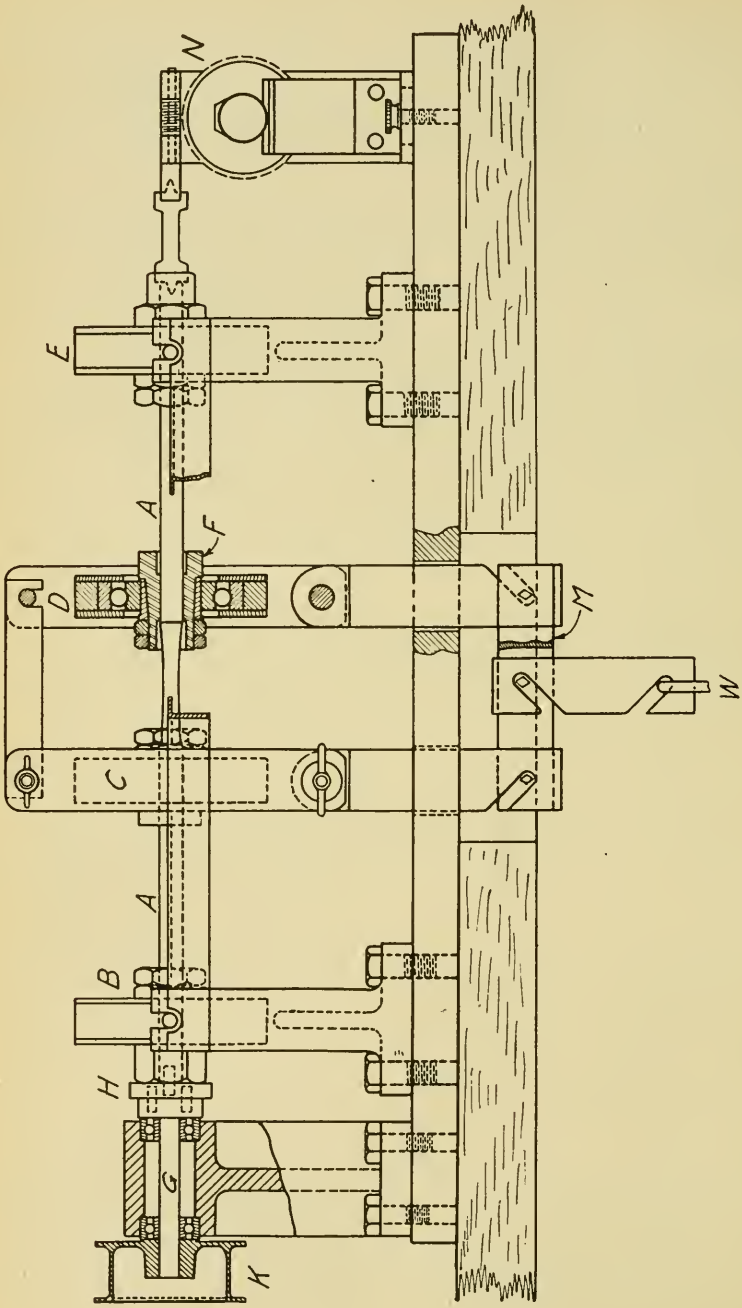


FIG. 1—ROTATING BEAM TYPE OF TESTING MACHINE EMPLOYED FOR CONDUCTING REVERSED STRESS TESTS

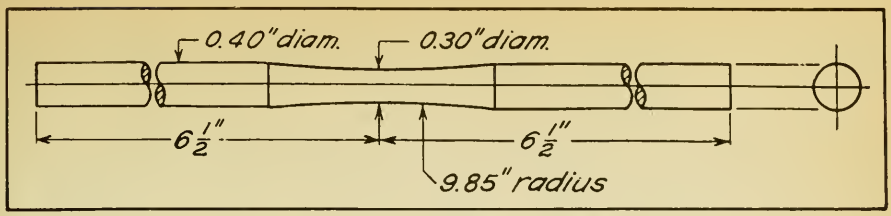


FIG. 2—SKETCH OF THE ROTATING BEAM SPECIMEN USED IN DETERMINING FATIGUE

not break at the places where the load was hung due to the localized stresses existing there. Fig. 2 shows the rotating beam specimen, which was used in the tests. To prevent variation in fatigue results due to the condition of the surface on the specimen, all fatigue specimens were finished in a standard manner, the final polish being prepared with No. 0 and No. 00 emery cloth. A system of numbering for specimens was adopted so that each specimen could be identified with respect to its position in the cross-section and in the length of the billet.

The tension, compression, and torsion tests were made by starting with an initial load and taking a reading of load and deformation, then applying an increment of deformation and taking another set of readings. The load was then reduced to the initial value and readings again taken, after which the load was increased until the extensometer showed the standard increment above the previous reading, and the load again reduced to its initial value. This procedure was continued until the yield point of the material was passed. From these data it was possible to determine the proportional elastic limit and also the elastic limit based upon permanent set.

In making the rotating beam tests a stress which would cause failure in a short time was applied to the first specimen. In successive specimens the stress was reduced until a stress was reached which the specimen could

Table I

Chemical Analysis of Steels Tested

Steel No.	Furnished by	Material furnished in	Content, per cent: Carbon	Chromium	Nickel	Silicon	Manganese	Phosphorus	Sulphur
1	Illinois Steel Co.	1 x 2-inch flats	1.20	....	....	0.19	0.25	0.021	0.021
3	John A. Roebling's Sons Co.	Billets, 4 inches square	0.52	....	....	0.24	0.56	0.037	0.029
4	John A. Roebling's Sons Co.	Billets, 4 inches square	0.37	....	....	0.16	0.58	0.032	0.035
5	Halcomb Steel Co.	1 x 2-inch flats	0.24	0.87	3.33	0.15	0.37	0.019	0.025
6	Carnegie Steel Co. through Standard Steel Co.	7/8 x 2-inch flats	0.93	....	....	0.03	0.38	0.017	0.045
7	Midvale Steel & Ordnance Co. through General Electric Co.	1 inch squares	0.41	0.18	3.41	0.25	0.75	0.020	0.020
9	American Rolling Mill Co.	1 inch rounds	0.02	....	....	0.02	0.03	0.005	0.042
10	Inland Steel Co.	15/16 inch squares	0.49	....	....	0.12	0.46	0.017	0.029
50	J. T. Ryerson & Son (Cold-drawn screw stock)	7/16 inch rounds	0.20	....	....	0.03	0.67	0.025	0.090
51	University of Illinois stock (Hot-rolled reinforcing rod)	1/2 inch rounds	0.18	....	....	0.06	0.37	0.013	0.039

withtand for 100,000,000 cycles without failures. Wherever possible these long time tests without failure were run on from three to five specimens for each of the steels investigated.

Tables III, IV and V give the principal results obtained from the various steels investigated. Figs. 3 and 4 show characteristic diagrams of test results for reversed stress tests. In these diagrams, which are plotted with logarithmic co-ordinates, values of unit stress S are plotted as ordinates and values of number of cycles of stress for rupture N are plotted as abscissas, and the diagrams are called S-N diagrams. A plotted point marked with an

Table II

Heat Treatment of Steels Tested

Steel		Structure	Heat Treatment
No. 1	1.20 carbon	Normalized	Heat to 1460 degrees Fahr.; hold 15 minutes; cool in furnace (this anneals the steel so that it can be machined); then heat to 1580 degrees Fahr.; hold 15 minutes; cool in furnace with door open.
		Sorbitic	First anneal as above; then heat to 1470 degrees Fahr.; quench in oil; reheat to 860 degrees Fahr.; hold 30 minutes; cool in air.
No. 3	0.52 carbon	Normalized	Heat to 1550 degrees Fahr.; hold 15 minutes; cool in air.
		Sorbitic	First normalize as above; then heat to 1450 degrees Fahr.; hold 15 minutes; quench in water; reheat to 1200 degrees Fahr.; cool in air.
No. 4	0.37 carbon	Normalized	Heat to 1495 degrees Fahr.; hold 15 minutes; cool in furnace with door open.
		Sorbitic, Treatments A and B	This steel was not first normalized. Heat to 1550 degrees Fahr.; hold 15 minutes; quench in water; reheat to 1050 degrees Fahr.; cool in air.
No. 5	chrome-nickel	Treatment A	Steel received annealed. Heat to 1525 degrees Fahr.; quench in oil; reheat to 700 degrees Fahr.; quench in oil.
		Treatment B	Steel received annealed. Heat to 1525 degrees Fahr.; hold for ½ hour, quench in oil. Reheat to 1450 degrees Fahr.; quench in oil. Reheat to 1200 degrees Fahr.; hold for 1 hour; cool in furnace.
		Treatment C	Steel received annealed. Heat to 1525 degrees Fahr.; hold for ½ hour, quench in oil. Reheat to 1450 degrees Fahr.; quench in oil. Reheat to 1200 degrees Fahr.; hold for 1 hour; quench in water.
No. 6	0.93 carbon	Normalized	Heat to 1600 degrees Fahr.; hold 15 minutes; cool in air.
		Pearlitic	First normalize as above; then heat to 1450 degrees Fahr.; hold 15 minutes; cool in furnace.
		Sorbitic	First normalize as above; then heat to 1450 degrees Fahr; hold 15 minutes; quench in oil; reheat to 1200 degrees Fahr.; hold 30 minutes; cool in air.
		Troostitic	First normalize as above; then heat to 1450 degrees Fahr; hold 15 minutes; quench in oil; reheat to 850 degrees Fahr.; hold 30 minutes; cool in air.
No. 7	nickel	Treatment B	Normalize by heating to 1525 degrees Fahr. and cooling in furnace; then heat to 1525 degrees Fahr.; quench in oil; reheat to 1210 degrees Fahr.; hold 2 hours; cool in furnace.
No. 9	0.02 carbon	Ferrite	Tested as received.
No. 10	0.49 carbon	Normalized	Heat to 1700 degrees Fahr.; hold 20 minutes; cool in air.
		Sorbitic	First normalize as above; then heat to 1427 degrees Fahr.; quench in water; reheat to 1200 degrees Fahr.; cool in furnace.
No. 50	Cold-drawn	As received	
		Annealed	Heated to 1300 degrees Fahr.; hold for 15 minutes; cool in furnace.
		Annealed	Heated to 1550 degrees Fahr.; hold for 15 minutes; cool in furnace.
No. 51	Hot-rolled	As received	
		Cold stretched	Reduced to diameter of 0.44-inch; then heated to 500 degrees Fahr.; cool in furnace.
		Cold stretched	Reduced to diameter of 0.48-inch; then heated to 500 degrees Fahr.; cool in furnace.
		Cold bent	Bent to an angle of 45 degrees at the middle, straightened cold.

arrow indicates that the specimen was not broken at the end of the test. Altogether 963 reversed stress tests were made; 10 different steels were tested, with various heat treatments, numbering 23 in all. For each treatment of each steel the test results were plotted as an *S-N* diagram.

The *S-N* diagram given in Figs. 3 and 4 indicate that up to some value of *N* the results of the reversed stress tests may be well represented by a sloping straight line, and that at this critical point on the *S-N* diagram there is a decided break, and for higher values of *N* a horizontal straight line seems to represent the relation between *S* and *N*, up to a value of *N* of

Table III
Results of Tension Tests

Steel	Tension: Proportional elastic limit, Pounds per square inch	Tension: Yield point, Pounds per square inch	Tension: Ultimate, Pounds per square inch	Tension: Per cent of elongation	Tension: Per cent of reduction of area	Endurance limit Rotating beam machine, Pounds per square inch
0.02 carbon—As received	16,100	19,000	42,400	48.3	76.2	26,000
Hot rolled—As received	38,200	40,300	61,500	41.0	66.7	28,000
Hot rolled—Reduced to 0.48-inch	60,000	63,300	67,600	22.3	63.3	35,000
Hot rolled—Reduced to 0.44-inch	69,600	None	73,400	14.2	59.5	41,000
Hot rolled—Bent cold and straightened	.....	.....	.....	....	....	30,000
Cold drawn—As received	55,200	None	86,800	13.8	49.3	41,000
Cold drawn—Annealed at 1300 degrees Fahr.	26,700	29,500	56,600	41.3	65.5	29,000
Cold drawn—Annealed at 1550 degrees Fahr.	28,000	30,000	57,700	40.8	63.2	25,000
0.37 carbon normalized	34,500	34,900	71,900	29.4	53.5	33,000
0.37 carbon sorbitic—Treatment A	80,600	87,300	102,600	23.3	65.1	57,000
0.37 carbon sorbitic—Treatment B	61,500	63,100	94,200	25.0	63.0	45,000
0.49 carbon sorbitic	67,700	69,700	96,900	23.5	57.8	48,000
0.52 carbon normalized	45,400	47,600	98,000	24.4	41.7	42,000
0.52 carbon sorbitic	80,300	84,300	111,400	21.9	56.6	55,000
0.93 carbon pearlitic	28,000	33,400	84,100	24.8	37.2	30,500
0.93 carbon sorbitic	60,300	67,600	115,000	23.0	39.6	56,000
0.93 carbon troostitic	97,200	None	188,300	9.9	29.3	98,000
1.20 carbon normalized	58,600	60,700	116,900	7.9	11.6	50,000
1.20 carbon sorbitic	120,400	130,100	179,900	9.0	15.2	92,000
3½ nickel—Treatment B	82,400	91,100	111,800	23.6	60.2	63,000
Chrome-nickel—Treatment A	115,500	128,100	138,700	18.2	61.8	68,000
Chrome-nickel—Treatment B	101,700	103,700	113,300	24.2	68.7	65,000
Chrome-nickel—Treatment C	86,200	100,500	114,200	23.2	69.3	67,000

Table IV
Results of Compression and Torsion Tests

Steel	Compression: Proportional elastic limit, Pounds per square inch	Compression: Yield point, Pounds per square inch	Compression: Ultimate Pounds per square inch	Torsion: Proportional elastic limit, Pounds per square inch	Torsion: Yield point, Pounds per square inch	Modulus of elasticity
0.02 carbon—As received	19,200	20,600	31,200	12,500	13,600	11,770,000
0.37 carbon normalized	36,300	38,100	59,200	20,300	22,500	11,790,000
0.37 carbon sorbitic—Treatment A	75,800	84,500	102,800	51,600	60,200	11,960,000
0.49 carbon sorbitic	55,900	60,100	76,500	36,800	None	12,150,000
0.52 carbon normalized	47,800	51,000	78,700	30,000	34,600	11,720,000
0.52 carbon sorbitic	84,400	87,400	97,800	52,200	None	12,115,000
0.93 carbon pearlitic	23,500	29,700	69,200	15,600	22,500	11,880,000
0.93 carbon sorbitic	64,800	72,700	97,100	42,000	None	12,130,000
0.93 carbon troostitic	106,500	None	.....	75,200	None	11,960,000
1.20 carbon normalized	55,300	57,900	96,500	36,500	39,700	11,700,000
1.20 carbon sorbitic	102,700	111,500	149,200	80,600	None	11,940,000
3½ nickel—Treatment B	86,400	94,000	95,100	55,500	None	11,890,000
Chrome-nickel—Treatment A	122,600	130,100	133,000	72,400	84,900	11,510,000
Chrome-nickel—Treatment B	97,800	100,000	100,300	62,500	None	11,980,000
Chrome-nickel—Treatment C	91,500	97,400	99,900	62,300	None	12,020,000

100,000,000 cycles of stress, with no indication of a further break in the diagram. This critical point was a characteristic of the *S-N* diagrams for all steels tested. So far as can be seen from test results, for a value of *S* lower than the critical value corresponding to this break in the *S-N* diagram, the material would withstand an indefinite number of reversals of stress.

It is, of course, possible that the relation between *S* and *N* is of such a

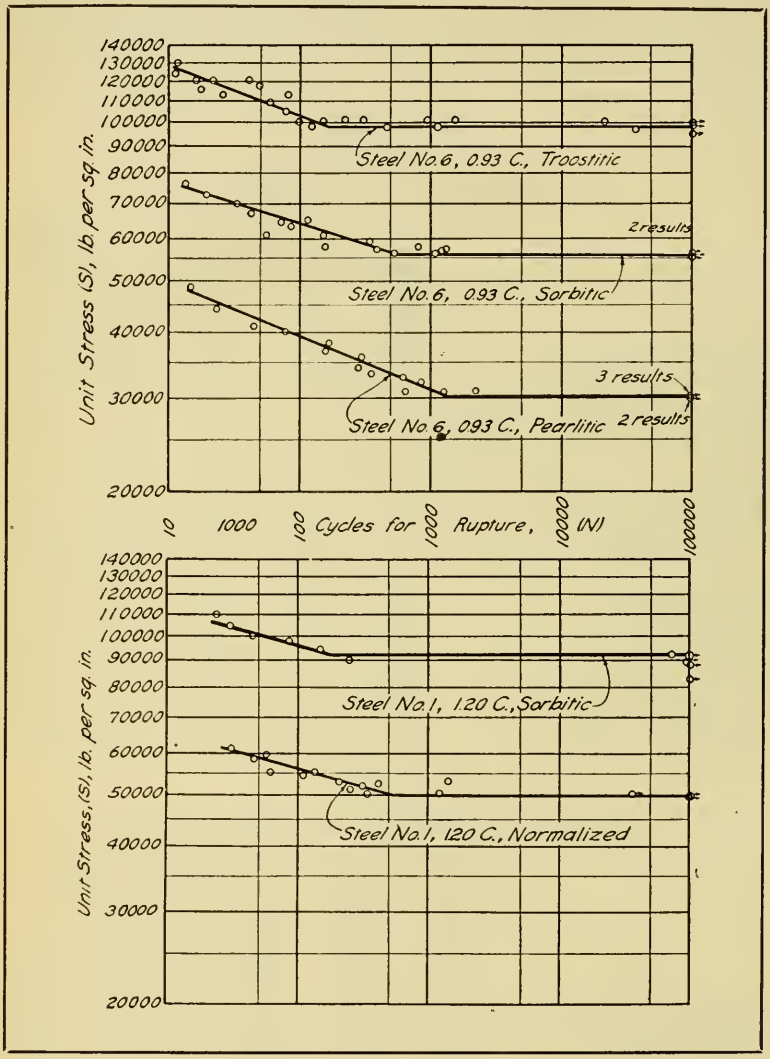


FIG. 3—TWO CHARACTERISTIC CURVES PLOTTED FROM RESULTS OF REVERSED STRESS TESTS. LOGARITHMIC SCALES HAVE BEEN USED FOR CONVENIENCE

nature that for some value of *N* beyond 100,000,000 the *S-N* diagram again slopes downward, or that for values of *N* greater than 100,000,000 the *S-N* diagram is a line with a very slight downward slope rather than an ab-

solute horizontal line. However, in view of the fairly sharp break shown in the diagram, and of the range and number of tests made, it is believed that the unit stress S corresponding to the horizontal part of an S-N diagram for steel may be regarded as a limit below which an indefinite number of reversals of stress will not cause failure. To this limiting stress the name *endurance limit* has been given. It should be noted that for all the steels

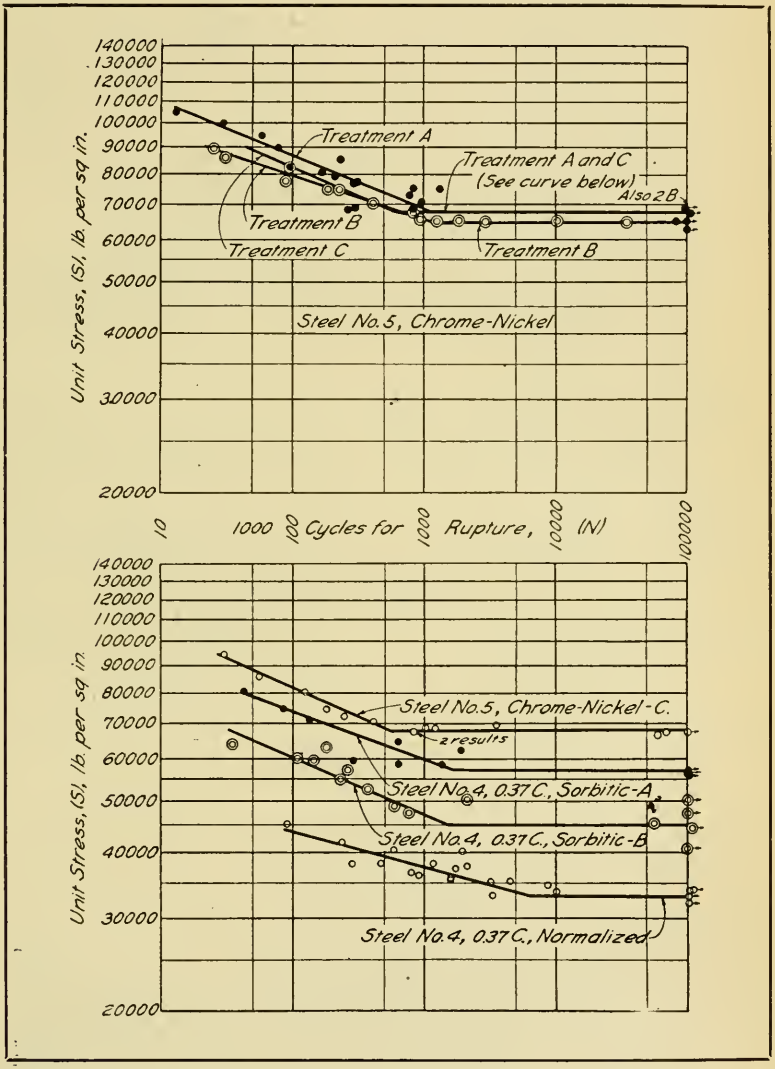


FIG. 4—TWO MORE CHARACTERISTIC CURVES PLOTTED FROM RESULTS OF REVERSED STRESS TESTS. LOGARITHMIC SCALES HAVE BEEN USED FOR CONVENIENCE

tested the endurance limit was developed at a value of N less than 10,000,000. It is believed that the series of reversed stress tests made in this investigation furnish a clearer demonstration of the existence and magnitude of an en-

Table V

Results of Hardness Impact, Francke and Reversed Stress Tests

Steel	Hardness Brinell	Hardness Sclero-scope	Impact Bending Energy of rupture foot pounds	Impact Tension Energy of rupture foot pounds	Impact Tension Per cent of elongation	Impact Tension Per cent of reduction of area	Endurance Limits Farmer rotating beam, Pounds per square inch	Endurance Limits Upton-Lewis reversed bending, Pounds per square inch	Endurance Limits Olsen-Foster reversed torsion, Pounds per square inch	Francke bending FR Point in Francke test	Repeated impact Number of double blows
0.02 carbon—As received	69	18	19.3	84.9	27.0	72.7	26,000	23,000	12,500	.....	260
Hot rolled—As received	..	..	....	....	....	....	28,000	.....	.....	.....	242
Hot rolled—Reduced to 0.48-inch	..	..	....	....	....	....	35,000	.....	.....	.....	280
Hot rolled—Reduced to 0.44-inch	..	..	....	....	....	....	41,000	.....	.....	.....	361
Hot rolled—Bent cold and straightened	..	..	....	....	....	....	30,000	.....	.....	.....	...
Cold drawn—As received	..	..	....	....	....	....	41,000	.....	.....	.....	316
Cold drawn—Annealed at 1300 degrees Fahr.	..	..	....	....	....	....	29,000	.....	.....	.....	202
Cold drawn—Annealed at 1550 degrees Fahr.	..	..	....	....	....	....	25,000	.....	.....	.....	223
0.37 carbon normalized	132	18	15.8	168.4	32.4	52.7	33,000	30,000	16,000	33,000	183
0.37 carbon sorbitic—Treatment A	209	26	53.2	163.2	24.0	62.8	57,000	.....	32,500	.....	550
0.37 carbon sorbitic—Treatment B	..	..	....	....	....	....	45,000	.....	.....	44,000	503
0.49 carbon sorbitic	197	23	22.5	152.3	24.0	55.1	48,000	39,000	26,000	.....	319
0.52 carbon normalized	193	24	13.2	188.5	24.2	45.6	42,000	32,000	.....	39,500	275
0.52 carbon sorbitic	227	30	21.4	172.0	22.2	55.1	55,000	44,000	.....	66,000	486
0.93 carbon pearlitic	162	23	2.2	141.3	21.2	34.5	30,500	28,500	16,300	34,000	66
0.93 carbon sorbitic	227	31	3.3	193.2	21.6	43.9	56,000	44,000	.....	.....	128
0.93 carbon troostitic	380	51	4.4	186.8	15.0	41.3	98,000	.....	52,000	.....	227
1.20 carbon normalized	224	31	1.9	88.8	8.8	14.6	50,000	45,000	.....	.....	39
1.20 carbon sorbitic	369	45	2.0	109.1	6.3	11.0	92,000	.....	.....	.....	172
3½ nickel—Treatment B	242	28	41.0	179.9	22.8	57.4	63,000	.....	.....	.....	524
Chrome-nickel—Treatment A	291	36	45.4	173.8	17.0	61.7	68,000	52,000	37,000	62,000	1073
Chrome-nickel—Treatment B	247	28	53.8	175.3	22.2	63.2	65,000	.....	31,500	.....	714
Chrome-nickel—Treatment C	246	29	56.0	187.6	23.4	67.0	67,000	.....	.....	.....	722

durance limit than has been furnished by any previous tests made on this subject.

Fig. 5 has been drawn to show the relation between the endurance limit, the proportional elastic limit, and the tensile ultimate strength. The endurance limit as determined by the temperature test is also shown and is discussed later. These curves make clear that the proportional elastic limit cannot be used as a criterion of fatigue strength. The ultimate strength is a somewhat better criterion than the proportional elastic limit. It will be noted that, in general, the proportional elastic limit and the ultimate strength both increased as the endurance limit increases.

It should be noted that the determination of the elastic limit and the ultimate strength depends upon the average properties of a considerable mass

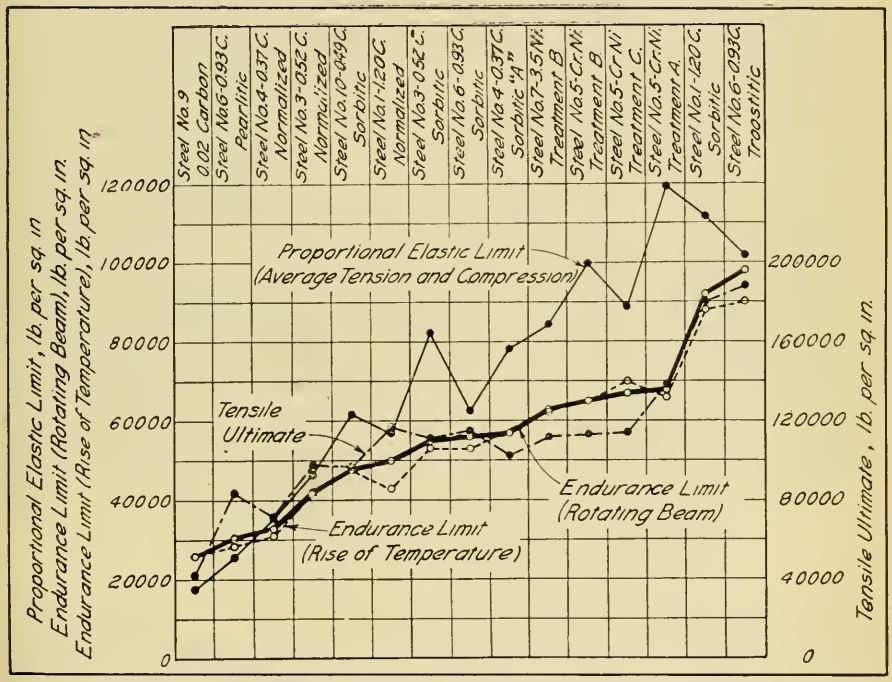


FIG. 5—CURVES SHOWING RELATION BETWEEN ENDURANCE LIMIT, PROPORTIONAL ELASTIC LIMIT, AND TENSILE ULTIMATE STRENGTH

of material. A minute defect, such as a nick on the surface, an incipient crack in the structure, or a localized stress resulting from heat treatment, will not in general affect the determination of the elastic limit to an appreciable extent. On the other hand, such a localized effect may readily act as a nucleus for structural damage which spreads under repeated stress in the form of minute cracks, with continued localized stress present at the roots of these cracks, and finally causes failure.

By reference to Table III it is seen that in none of the steels did the endurance limit under completely reversed stress fall below 36 per cent of the ultimate tensile strength; in only one metal did the endurance limit fall below 40 per cent of the ultimate tensile strength, while for several metals the endurance limit was more than 50 per cent of the ultimate tensile strength. In this connection it should be noted that the steels tested were to a high

Table VI

Endurance Limit Tests Are Compared

No.	Steel	Endurance limit, pounds per square inch — Rotating beam test	Endurance limit, pounds per square inch — Rise of temperature test
1	1.20 carbon normalized.	50,000	43,000
	Sorbitic	92,000	88,000
3	0.52 carbon normalized.	42,000	41,500
	Sorbitic	55,000	53,000
4	0.37 carbon normalized.	33,000	31,000
	Sorbitic—Treatment B.	45,000	49,000
5	Chrome-nickel—Treatment A	68,000	66,000
	Treatment B	65,000	65,000
	Treatment C	67,000	70,000
6	0.93 carbon pearlitic	30,500	28,500
	Sorbitic	56,000	53,000
	Troostitic	98,000	90,000
7	3.5 nickel—Treatment B	63,000	62,500
9	0.02 carbon—As received	26,000	26,000
10	0.49 carbon sorbitic	48,000	48,000
50	Cold drawn—As received	41,000	41,500
	Annealed at 1300 degrees Fahr.	29,000	27,500
51	Hot rolled, 0.18 carbon—As received	28,000	27,000
	Reduced to 0.48-inch	35,000	38,500
	Reduced to 0.44-inch	41,000	40,500
9	0.02 carbon, tested on Olsen-Foster reversed torsion machine	12,500	13,000
	Tested on Upton-Lewis reversed bending machine	23,000	27,000

degree free from inclusions and other internal defects, that the specimens had no abrupt changes of outline, and that they had a good surface finish.

Fig. 6 shows the relation between the endurance limits and Brinell hardness, Charpy impact bending, Charpy impact tension, and repeated impact results. It is evident that the impact results cannot be used as a criterion of fatigue strength. The Brinell hardness number, however, shows a consistent relation to the endurance limit. It is not clear why this should be the case, and the writers offer no explanation other than that of an empirical

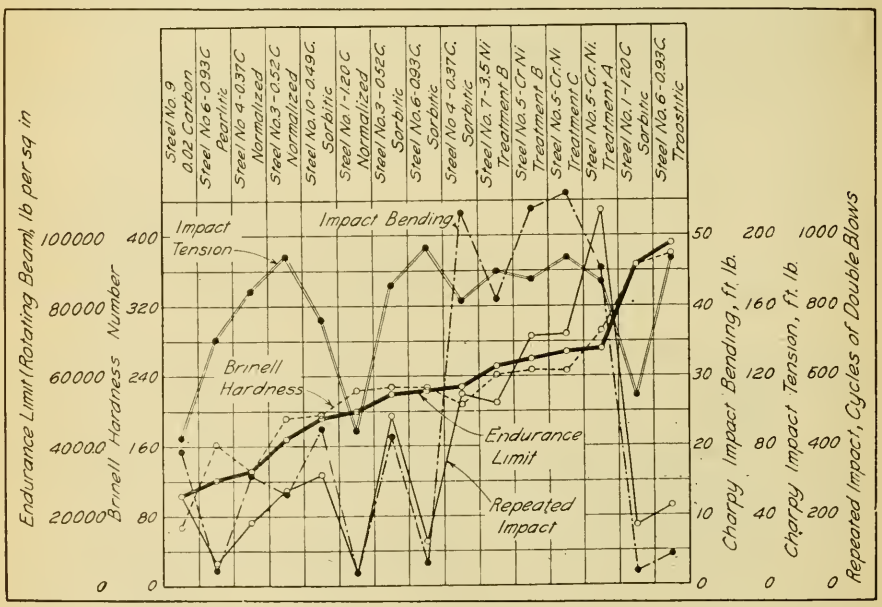


FIG. 6—CURVES SHOWING RELATION BETWEEN ENDURANCE LIMIT, BRINELL HARDNESS, IMPACT BENDING, IMPACT TENSION AND REPEATED IMPACT RESULTS

relation. The rise of temperature test described in the next paragraph, is a short time test for endurance strength which gives more accurate results than does the Brinell test, and which seems to have a rather more logical basis.

It was found that the endurance limit for the steels tested could be predicted with a good degree of accuracy by the measurement of rise of temperature under reversed stress applied for a period of a few minutes or less.

This action is explicable in view of the intercrystalline and intracrystalline slippage under repeated stress, which is shown by the miscroscope.

The apparatus used in making the temperature test is shown in Fig. 7. The machine used was designed to test the regular 13-inch, rotating beam specimen, Fig 2, and to produce the same type of stress as that produced in the rotating beam machine used for the main series of tests described in

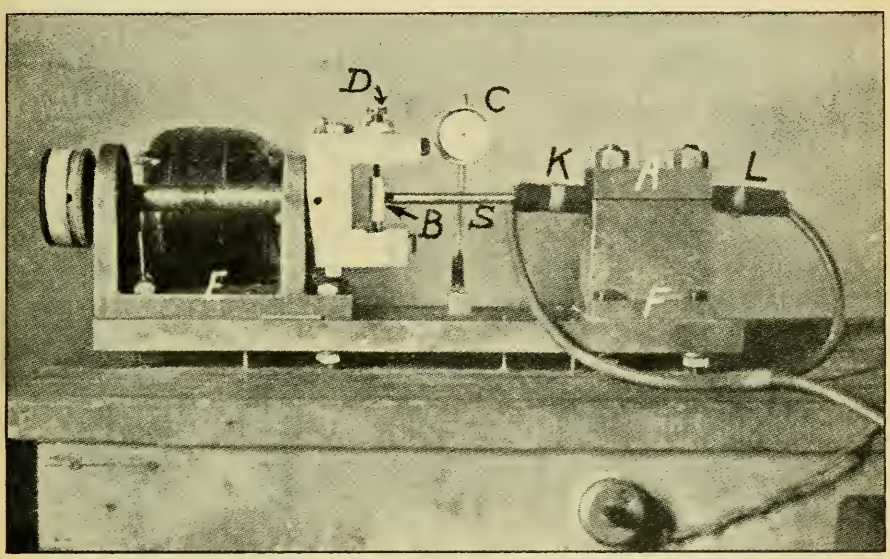


FIG. 7—TEMPERATURE TEST APPARATUS WHICH HAS BEEN DEVISED FOR PREDICTING ENDURANCE LIMITS OF SPECIMENS

this article. As shown in Fig. 7, the specimen *S* is held horizontally in V-shaped grips, *A*. The load is applied on a ball bearing, *B*, at the end of the specimen, the bearing being heat insulated from the specimen by a fiber collar 1/16-inch thick. The machine is also heat insulated from the base at points *E* and *F*, to prevent heat traveling from the bearings through the base to the specimen. The load on the specimen is measured by reading the deflection of the dial *C*, a load-deflection curve for the specimen having been previously obtained by recording a set of loads and corresponding deflection readings. The load can be varied by an adjusting screw *D*, in the head of the machine. A thermocouple cannot be attached readily to a rotating specimen, and it will be noted that the machine is so designed that the specimen does not turn, but that the head of the machine rotates. The left-hand end of the specimen is thus moved in a circle concentric with its axis, the radius of the circle being the deflection corresponding to the desired stress.

Differential copper-constantan thermocouples were used to measure the rise of temperature. One couple was attached at the section of greatest stress *K*, and was held directly against the specimen by means of tape. The other

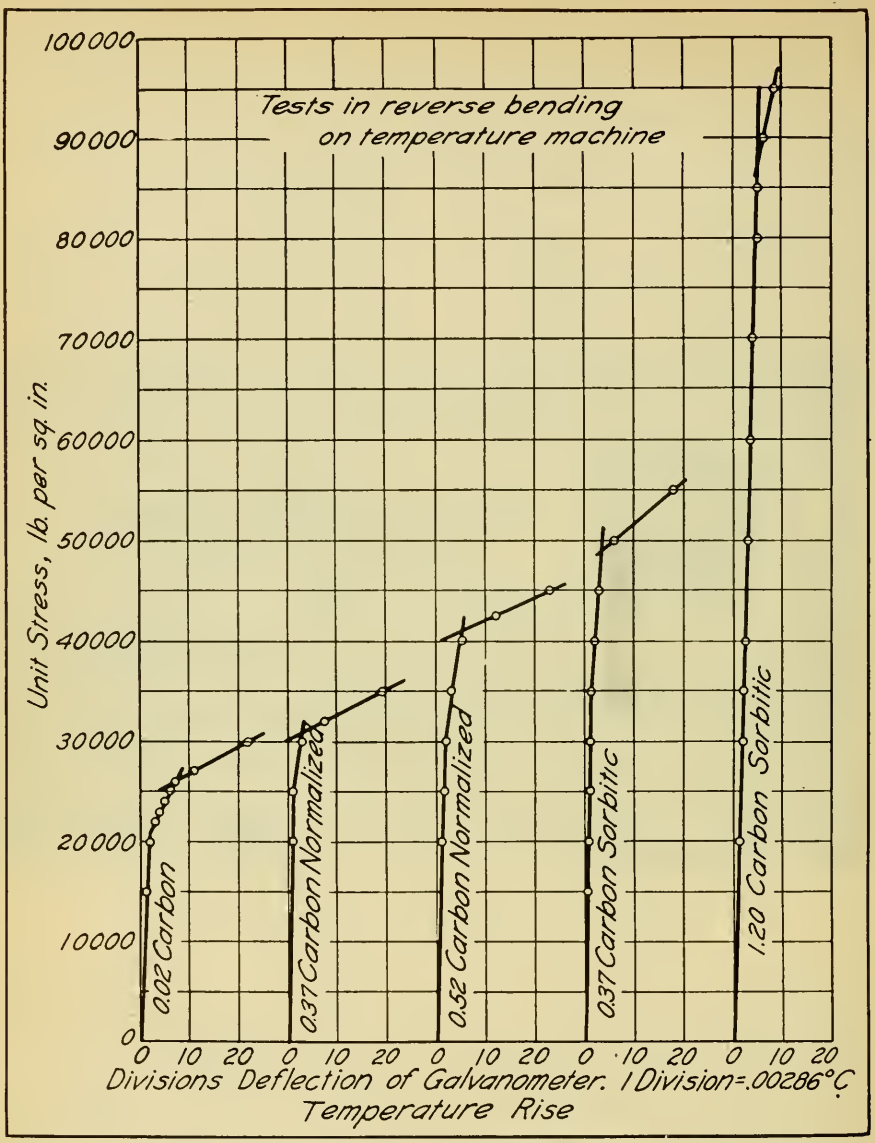


FIG. 8—TYPICAL CURVES SHOWING INCREASE IN TEMPERATURE WITH INCREASED STRESS

couple was at L, a section of zero stress, and was separated from the specimen by a single layer of thin paper. The couples were connected in series and the free wires lead to a galvanometer. When the couples were at the same temperature no deflection of the galvanometer was shown but when the temperature became different a corresponding deflection occurred.

The temperature test finally adopted as a standard consists in running the machine at a speed of 1000 revolutions per minute for 30 seconds, using a known stress and recording the maximum deflection of the galvanometer.

Then with a series of such readings, corresponding to a series stresses, a curve is plotted to show the increase in temperature with increase of stress. The point at which the curve shows a sharp break corresponds to the endurance limit. Typical curves are shown in Fig. 8. In the cases of sorbitic structures in plain carbon steel and in that of alloy steels it was found necessary to increase the time of the run at each stress, from 30 seconds to 2 minutes, since these materials are slower in heating under stress.

A reference to Table VI and Fig. 5 shows a very good degree of coincidence between the values of endurance limit determined by the temperature test and those values determined by long time rotating beam tests. The temperature test was suggested and to some extent used by C. E. Stromeyer, Manchester, England, as long ago as 1913. He did not have the opportunity, however, of carrying out a sufficient number of long time tests to establish thoroughly the temperature limit as identical with the endurance limit under repeated stress.

It should be stated that the credit of developing the temperature test in connection with the present investigation should be given to J. W. Harsch, a member of the test party of the present investigation, and to Prof. W. J. Putnam of the department of theoretical and applied mechanics of the University of Illinois..

Previous investigators have shown that the shape of the specimen may exert a great influence on the endurance strength of the material. Square shoulders and sharp notches are known to reduce the endurance limit as much as 50 per cent. A study of this matter was first made in this investigation on a 0.49 per cent carbon sorbitic steel. It was found that specimens which had their diameter reduced by a radius of 1 inch were almost as strong as those in which a radius of 9.85 inch was used. A 1/4-inch radius reduced the strength about 8 per cent, square shoulders reduced the strength about 51 per cent, and a V-notch reduced the strength about 60 per cent. Square shoulders and a 1/4-inch radius showed about the same effect on a soft 0.02 per cent carbon steel as they did with the harder steel first mentioned.

It has been known that the condition of the surface of a specimen may exert a marked influence on the fatigue strength of steel. A study of this matter was first made on a 0.49 per cent sorbitic steel carbon. One series of specimens was finished carefully in order to remove all scratches and was finally given a high rouge polish. It was found that these specimens were only slightly stronger than those finished with the standard finish. Specimens with a ground finish were slightly weaker than those with the rouge finish, smooth turned still weaker, and rough turned weaker even than the smooth turned. The rough turned specimens were about 18 per cent lower in endurance limit than those finished with the rouge polish.. Similar results on the smooth turned and rough turned specimens were found with a soft 0.02 per cent carbon steel.

To determine whether stressing a specimen above its normal endurance limit would have a serious effect on the endurance limit under subsequent stresses, a number of different combinations of overstresses and cycles of rupture were tried on a 0.49 per cent sorbitic steel carbon. For instance, one series of specimens was given 5000 cycles of stress at a unit stress 10 per cent higher than its normal endurance limit. These specimens were then tested in the usual way to determine whether the overstressing had changed the endurance limit. It was found that 10 per cent and 20 per cent of the overstress applied 5000 times, 29 per cent of overstress applied 1000 times, and 38 per cent of overstress applied 100 times did not reduce the endurance limit

appreciably. On the other hand, 35 per cent of overstress applied 1000 times reduced the endurance limit about 4 per cent, and 29 per cent of overstress applied 5000 times reduced the endurance limit 11 per cent. It is evident therefore that a material may be able to withstand a considerable amount of overstress if the overstress is applied only a comparatively small number of times. Tests on a hard, high carbon steel gave similar results to those above mentioned, the percentage of reduction being somewhat higher than for the soft steel.

It is a well known fact that the effect of subjecting steel to a tensile stress beyond the yield point is to raise the static elastic strength to a marked degree, as is illustrated by the strength of cold-drawn and cold-rolled steel. It was found in the case of a 0.18 per cent carbon steel that the effect of such cold work was less marked on the endurance limit than on the static elastic strength, though some increase of endurance limit was observed after cold working. Annealing of commercial cold-drawn screw stock was found to reduce its endurance limit.

Figs. 3 and 4 illustrate the effect of heat treatment on the endurance limit. In the soft condition of the pearlitic structure of the 0.93 per cent carbon steel the material has an endurance limit of 30,000 pounds per square inch. This can be increased by 84 per cent if the steel is given a sorbitic structure by heat treatment, and by 221 per cent when it is given a troostitic structure. In general, a heat treatment which raises the static elastic strength and the ultimate tensile strength raises the endurance limit also, but the increase in static strength is not a reliable indicator of the amount of increase in endurance limit.

In those cases in which the same steel was tested in a hard and a soft condition the results show that giving the material a sorbitic structure by heat treatment may greatly increase the endurance limit without much sacrifice of ductility. The results thus far obtained on eight different steels in reversed torsion indicate that the ratio of the endurance limit in torsion to the endurance limit in bending is about 0.52.

With one soft steel it was found that the computed stress at the endurance limit in bending was actually about 33 per cent higher than the proportional elastic limit in tension. This material was almost pure ferrite and the result indicates that homogeneity of structure is a valuable factor in giving a high resistance against fatigue. Results indicate that thorough annealing also tends to produce a condition which will give a high ratio of endurance limit to proportional elastic limit. It should be noted that it is quite possible for a steel to have a high ratio of endurance limit to proportional limit, when both values of endurance and proportional limit are low. Only one nickel and one chrome-nickel steel were investigated. The results indicate that the alloy steels have somewhat higher endurance limits for the same ductility, as compared with plain carbon steels.

One theory of the nature of the fatigue of metals is the crystallization theory. Often materials which have failed under repeated stress show a crystalline fracture, and this theory supposed that under the action of repeated stresses the internal structure of a metal changed from fibrous to crystalline, and that different metals varied in their resistance to this change.

The use of the microscope in examining the structure of metals has discredited this theory. All metals are seen to be of a crystalline structure under all service conditions, and no evidence of appreciable change of structure can be observed in a metal subjected to repeated stress. There does appear to be a breaking down of crystals as indicated by the formation of

minute cracks or slip bands extending across the crystal. The crystallization theory of failure under repeated stress practically has been abandoned today.

A second theory of failure of metals under repeated stress was that advanced by the distinguished German investigator, Bauschinger. His theory holds that under stress varying from zero to a maximum, it is possible for metals to acquire new elastic limits which may be anywhere between the original proportional elastic limit and the yield point, and may in some cases even exceed the yield point. These new elastic limits, or natural elastic limits, as Bauschinger called them, depend upon the number of cycles of stress to which the material is subjected, being higher for the greater number of cycles. For stresses within the natural elastic limit the metal is assumed to possess indefinite endurance. Bauschinger's theory does not imply a change in the crystalline structure of the material, but does imply some change in the inherent nature of the material.

A third theory has been suggested by various investigators and was formulated by the writers, who later found that it had been elaborated by Gilchrist. This theory may be stated briefly as follows: Fracture in fatigue is caused by the statical breaking limit being exceeded at one point only, from which, when once started, rupture spreads. The raising of the stress at the point where fracture commences is due to an irregularity of the bar, which may be an irregularity or discontinuity in the metal, either on the surface or in the body of the bar.

This theory may be called the theory of nonhomogeneity or of localized stress. The effect of external nonhomogeneity due to scratches, tool marks, square shoulders, and notches is well known. Internal nonhomogeneity may be due to blow holes, pipes, inclusion of slag, irregularities of crystalline structure on account of the presence of two or more constituents of varying strength, variation in orientation of crystals, or it may be due to the presence of initial stresses caused by mechanical working or by heat treatment. This localized stress produces no appreciable effect under a single load, owing to the minute area over which it exists, but under load repeated many times, there is started from this area a microscopic crack at the root of which high localized stress exists and which, under repetitions of stress, spreads, finally causing failure.

The writers do not look upon these fatigue failures as being due necessarily to accidental flaws or irregularities. In practice they may often be due to such causes, but the uniformity of the results in the present tests points to the conclusion that the endurance limit is a property of the material just as much as the ultimate strength is. If in these tests the failure is due to flaws, then it is believed that these flaws are an inherent part of the structure of the particular steel which is being tested..

The following subjects are suggested for further investigation: The effect of repetition of stress not reversed; tests on other ferrous metals not covered in this investigation, especially various alloy steels; tests on nonferrous metals; detailed study of effect of heat treatment; tests in direct tension-compression; more complete study of reversed torsion; study of the mechanism of fatigue failure as revealed by the microscope; effect of repeated understressing; strength of cast metal under repeated stress and repair by heat treatment of structural damage due to repeated stress.

RECLAIMING HIGH CARBON GEARS

By R. L. Dowdell

FOR several years a tractor company has been practically scrapping a large number of splined jack-shaft gears. In Fig. 1 is shown one of these gears at about half size. Failure in service occurred in two ways. (1), By the stripping of the gear teeth; and (2), by the shearing of the spline at the base of the gear as indicated by the arrow in Fig. 1. With ordinary hardening and drawing operations these gears were made so brittle that they would fracture when tapped with a hammer, thus naturally all service tests on them failed. Specifications on the gears called for approximately 1.5 per cent chromium and 0.20 per cent carbon. They were to be carburized in a cyanide bath for a depth of 1/16 inch. In the heat treated or finished state the scleroscope hardness should fall between 85 and 95.

Microscopic examination of sections taken at right angles to the main axis through some of the gears which had failed, showed that they had a great depth of hardening. In fact a large number of them were found

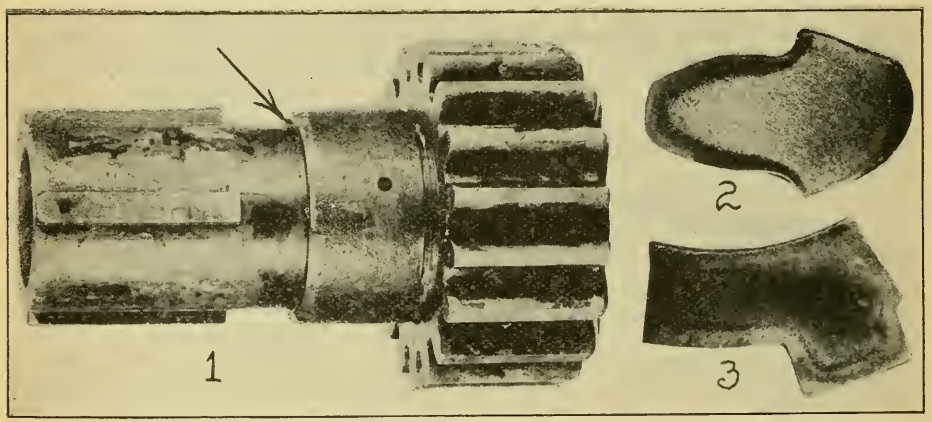


Fig. 1—One of the splined jack-shaft gears. About one-half actual size. Fig. 2—Cross section of gear tooth drawn at 200 degrees Cent. for 1 hour. X 2. Fig. 3—Cross section of spline drawn at 200 degrees Cent. for 1 hour. X 2. Both Figs. 2 and 3 show a martensite case with troostite at a depth of about 1 millimeter. See Figs. 7 and 8.

to be martensitic even in the centers of the largest sections. The grain size indicated that these gears had not been overheated thus the depth of hardening must have been due to some other influence. Several of these gears were normalized in order to change them into the pearlitic condition and observed on the microscope. This examination showed that they had been carburized completely to the center and instead of being 0.20 per cent carbon were found to be 0.75 per cent carbon. In Figs. 4 and 5 are shown the microstructure at the extreme edge and at the center respectively of one of these normalized gears.

As the decarburization of the gears by thermal means was impracticable, it was believed that these gears could be reclaimed by a heat treatment which would give them a tough core with a hard case by varying the internal structures without altering the carbon content. With this idea in mind

A paper presented by title at the Indianapolis Convention. The author, R. L. Dowdell, is instructor in metallography, University of Minnesota, St. Paul, Minn.

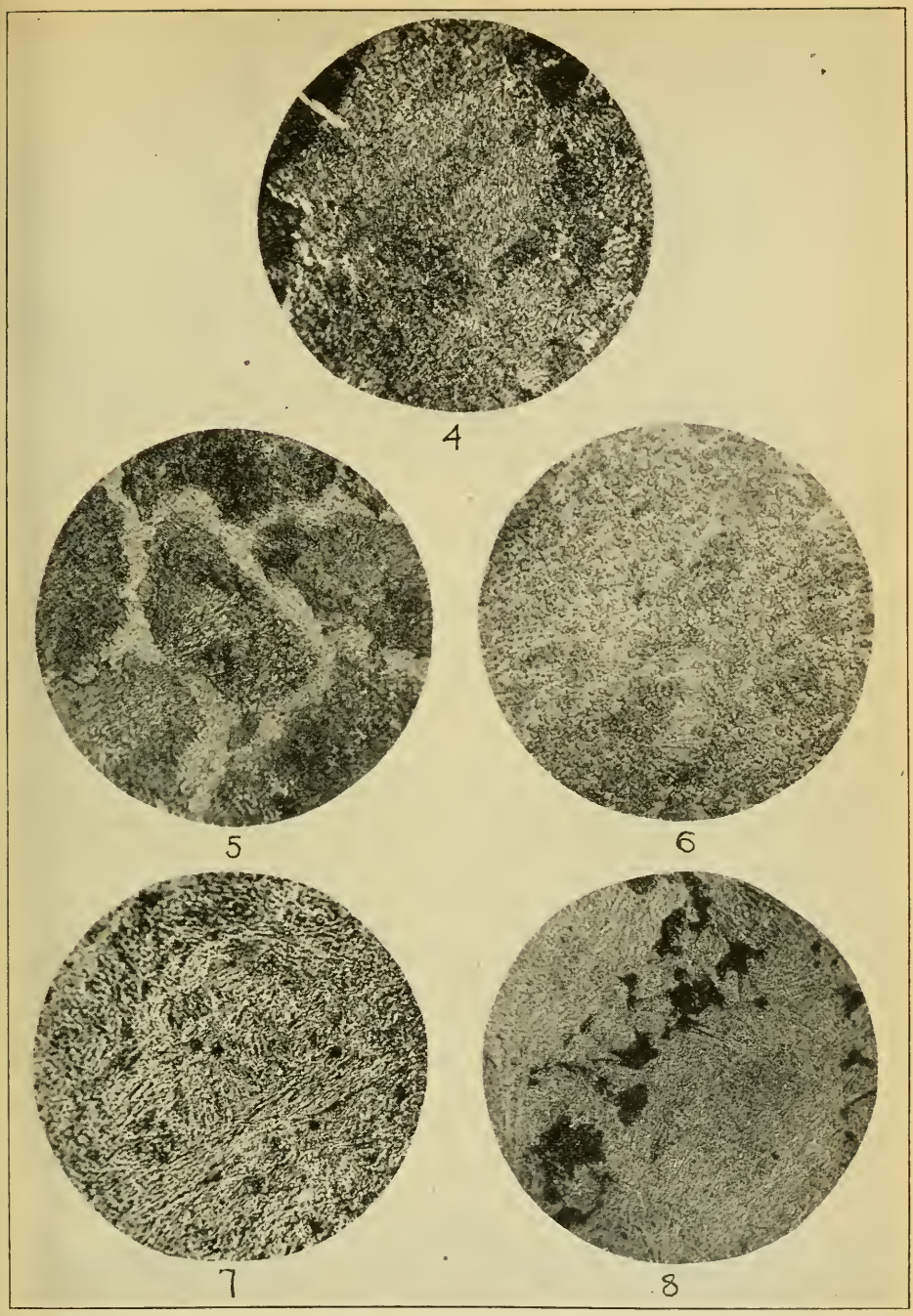


Fig. 4—Laminated pearlitic microstructure at extreme edge of normalized gear. Etched in picric acid. X 800. Fig. 5—Dark area shows laminated pearlite and light area shows ferrite at center of normalized gear. Etched in picric acid. X 800. Fig. 6—Granular pearlitic structure of annealed gear. Etched in picric acid. X 800. Fig. 7—Martensitic structure in case of gear drawn at 200 degrees Cent. for 1 hour. Etched in picric acid. X 800. Fig. 8—Light area shows martensite and dark area shows troostite at depth of 1 millimeter in gear drawn at 200 degrees Cent. for 1 hour. Etched with picric acid. X 800.

a treatment was devised and was found to be successful in making these gears serviceable. The method employed is outlined in this article.

The gears were charged into a cold furnace, brought up to a temperature of 770 degrees Cent. (1418 degrees Fahr.) and held for one hour. They were then cooled as slowly as possible through the critical range in order to form a granular pearlite throughout the gear. Fig. 6 shows the structure of these annealed gears. This granular pearlitic structure was desired in the core for two reasons: (1), Because of the high impact toughness of granular pearlite as compared with other microstructures in a high carbon steel; (2), when granular pearlite is once formed it goes into solution more slowly than other microstructures, lengthening the time required in the lead pot and tending to make the results more uniform. After this annealing operation the scleroscope hardness averaged 46 with a Brinell hardness of 212.

Packing for differential hardening was accomplished as follows: (A). Asbestos cord was laced between the gear teeth and tied around abrupt changes in section to avoid notch difficulties; and (B). Instead of using asbestos cord, a clay mixture was found to be satisfactory for keeping some of the areas soft. The mixture consisted of:

	Per cent
Fireclay	66
Water glass (Na_2 SiO_3)	20
Salt (NaCl)	7
Fibrous hardening compound	7
	100

The above was mixed with water so that it was just thin enough to stick to the steel surface to be kept soft. After the parts were clayed they could be dried at practically any rate of heating between temperatures of 100 and 200 degrees Cent. until it had set about as hard as concrete.

For hardening, the gears were heated in a lead pot containing practically 100 cubic inches of lead. Owing to the difference in the thickness of the section at the gear and spline ends of the piece, it was found that if only the gear end was submerged in the lead for 5 minutes and then the whole piece lowered for 4 minutes more, with a finishing temperature of 770 degrees Cent.; the depth of hardening was practically 1/16 inch deep. These pieces were quenched in a medium heavy quenching oil. After quenching the clay was broken off and the pieces drawn.

The gears were drawn at 200 degrees Cent. for one hour. Fig. 2 shows a section through a gear tooth and Fig. 3 a section through the spline at a magnification of two diameters. The case is of martensite at the outside while about one millimeter further in troostite appears as is shown by Figs. 7 and 8 respectively. The core in this differential hardening operation remained unchanged as it was not allowed to go above the Ac transformation. The scleroscope hardness of the case after these operations averaged 90.

This type of heat treatment can be used successfully in reclaiming materials of similar nature which have undergone expensive machining operations thus making them too valuable to scrap. If large lead pots are used, the temperature of the bath can be kept constant, therefore the time of immersion of the section is the main variable in the heat treatment. An air bath type of furnace would probably be unsatisfactory for this type of treatment. Uniform sections can be treated more easily than sections with variable dimensions. Most of the work in this investigation was performed by a group of engineering students of whom A. R. Kleinschmidt deserves the most honorable mention.

OCCURRENCE OF OXIDES AND NITRIDES IN BOILER TUBE STEEL

By A. E. White and J. S. Vanick

THE influence of the solid compounds of oxygen and nitrogen, such as the oxides and nitrides, upon the properties of metals has of late been receiving some well deserved attention. Most of the work has been concentrated upon the nitrogenization of steel by ammonia and the study of compounds occurring in fusion welds. Recent progress in the study of ammonia nitrogenized iron and electric arc welds[1] has indicated the presence of compounds of nitrogen in these materials. In addition the occurrence of oxides in fusion welds has demanded attention. Perhaps an equally important field which is occasionally touched upon, involves the study of the origin and mode of occurrence of the solid compounds of gases in metals and the relation of these compounds to the structure and physical properties.

In the usual inspection, analysis and test of steel, the presence of nitrides and oxides may be overlooked entirely. In the hot working or cold working of the metal into its final shapes, the presence of these gases or their compounds may produce hot shortness or cold shortness, although this effect is frequently attributed to other causes. The fracture test, by revealing a decided brittleness, or the tensile test by indicating a lack of ductility, may issue a warning of the presence of dissolved gases or their solid compounds.

An example of the influence of nitrogen and oxygen upon steel which was recently brought to the attention of one of the authors, announced itself by the brittleness of several specimens of boiler tubing. An investigation of the properties and structure of the tubing was made with the purpose in view of locating the relation between the two.

A microscopic examination[2] of several specimens showed that the metal had, at some stage in the course of manufacture, been over-oxidized,[3] or, more correctly, allowed to absorb and retain an excess of nitrogen and oxygen. Since a sprinkling of nitrides and oxides was visible in the structure the corresponding gases must have been present in the metal in a quantity far in excess of that usually present in ordinary steel. The presence of an excess of gas in the metal may be due to one of two causes:

(a) The absorption and retention of gas by the liquid metal in the refining process, or

(b) The absorption of gas by the solid metal in some of the heating operations subsequent to refining.

Of these two sources of gas contamination, the former, in this case, appeared more probable. A polished but unetched surface of one of the

1. A resume of the literature on the effect of nitrogen in steels has been prepared by Comstock and Ruder, *Chemical & Metallurgical Engineering*. Vol. 22, No. 9, 1920, page 399. The same subject is included in an excellent bibliography compiled by Rawdon, Groesbeck and Jordan, Bureau of Standards, Technical Paper No. 179.

2. Acknowledgment is due the Bureau of Standards, Washington, for the use of the equipment of the metallurgy division for this work.

3. Steel, which has been held too long in the oxidation stage or steel poorly deoxidized frequently is spoken of as oxidized or over-oxidized steel. In the case of over blown bessemer steel, for instance, the possible presence of large amounts of nitrogen would make the designation incorrect.

A paper presented by title at the Indianapolis Convention. A. E. White is director department of engineering research, University of Michigan, Ann Arbor, Mich., and J. S. Vanick is metallurgist Fixed Nitrogen Research Laboratories, Washington.

specimens revealed a precipitation of small globules, sprinkled about in a matrix apparently free from other markings. Under high magnifications, the globules strongly resembled oxides and subsequent etching proved them to be oxides.

A surface representing a cross section showed them to be rather uniformly distributed throughout the matrix, although a slight tendency to form in concentric layers was noticeable. A longitudinal section, however, revealed them in the form of segmented strings or chains. The parallel-string distribution in the longitudinal section is significant in establishing the origin of the oxides. Apparently, oxygen or the oxide of iron has been dissolved in the molten metal and liberated upon cooling. The subsequent rolling and working had moved the particles into parallel rows. The uniform distribution of the oxides in the cross-sections was further characteristic of the precipitation of insoluble compounds from a cooled metallic solution. It is evident that such oxidation that may have occurred in the heating operations subsequent to casting would show a graduation in the quantity of oxide from the surface toward the interior of the sections.

Etching definitely established the position of the oxides with respect to the grain structure and revealed the presence of nitrides. The structures are recorded in Figs. 1 and 2 the difference between the two micrographs having been produced by a change in focus. The deeper color which the nitrides assume and their apparent projection above the reflecting surface, renders them visible above the plane of the image, whereas the oxide inclusions have been found to be more intensely revealed by focusing them below the plane of the image.

Fig. 1, illustrating the position of the oxides, shows them to be irregularly distributed and quite independent of the grain structure. The effect of mechanical working upon these inclusions in marshalling them into segmented cords or chains that agree in direction with the long dimension of elongated slag particles is evident from the micrograph.

The nitrogen compounds which occur in the structure require a closer observation for their detection. A close inspection of the surface discloses the thin, needle-like crystals which, except for their straightness, strongly resemble the short graphite flakes of cast iron. The plates appear to be rather uniformly distributed throughout the body of the tube thus lending support to the supposition that nitrogen has been dissolved in the molten metal, rather than absorbed, in some of the heating operations subsequent to casting.

The type of plate occurring in the specimens examined is shorter than that usually found in fusion welds or ammonia-nitrogenized iron and the number of plates that appear is much smaller. Nitrogen may be retained in solution in iron. It appears that in the present case the feebler precipitation of the nitrides is an indication of the smaller quantity of available compound-forming gas in the metal. A corresponding effect, however, may be induced by the temperature conditions prevailing during the final heating and cooling. For example, Ruder[4] and others, have shown that an absorption and diffusion of the nitride plates, similar to the absorption and diffusion of carbon in steel, takes place upon heating to 650 degrees Cent. Quenching from 650 degrees Cent. and above, prevents the precipitation of the nitride plates. Slow cooling usually permits their formation. However, the conditions necessary for controlling the precipitation of nitrogen compounds and the

4. Ruder, The Effect of Nitrogen in Steel, *Chemical & Metallurgical Engineering*, Vol. 22, No. 9, page 399.

physical effects attending the several types of structure have not yet been thoroughly established.

An interesting feature of the structure which is partly illustrated in Fig. 2 and 7, is the failure of the nitride plates to adopt a directional trend corresponding to the direction of working. For example, the prevailing slope of the plates shown in the center of Fig. 2, is north-west. This slope is inclined at an angle of approximately 45 degrees to the direction of working as marked by the oxide links. Since the tubes were hot worked, the nitrides were evidently in solution and their position in the equi-axed crystals that form upon cooling would be expected to be devoid of directional characteristics. It is possible that the intercleavage slip in the hot-worked crystals followed an angle of approximately 45 degrees to the direction of working. The opinion might then be ventured that the plates tend to form along directions corresponding to the cleavage angle, or in other words, that the plates exert an effort to collect along those cleavage planes that have been subjected to slip. This suggestion implies the ability of the individual crystals to expel their burden of dissolved nitride, much after the fashion of the expulsion of cementite in high carbon steels or the intercleavage expulsion of ferrite in nickel steels. The persistence of lines of flow in the hot-worked crystals in spite of an almost instantaneous recrystallization from the working temperature, through the precipitation temperaure must be assumed.

The directional characteristics described above are not consistently maintained throughout the specimens, hence additional evidence of this effect is necessary before the explanation may be accepted. It has been shown that the curved plates formed in the metallic globule inclusions of fusion welds, retain their curved form even after heating to 1000 degrees Cent.[5] This temperature is far above the solution temperature of the nitride plates in the ferrite matrix hence it appears that the cast from which the nitride is absorbed in heating retains its unity until the nitride is again precipitated upon cooling.

Figs. 3 and 4 illustrate the appearance of the nitride patches which are frequently mistaken for the eutectoid pearlite of ordinary carbon steels. To those familiar with the structure of nitrogenized iron, the identification of this constituent offers little difficulty. A weak etching reagent preferably is used and the structure gradually developed by repeated etchings. Nitric or picric acids are suitable for the purpose and boiling sodium picrate or the heat tinting methods adopted by Strauss,[6] may be used to advantage. The important points of resemblance between pearlite and the nitride patch are:

(a) The irregularity in surface contour.

(b) The darkening upon etching.

(c) The common preferences, then present in small quantities to collect at the grain boundaries.

Nitride patches usually lack the laminations characteristic of the iron-carbon eutectoid, pearlite. Instead their surface is roughened by irregular eddies or swirls. Comstock[7] has reported patches composed of fine needles. Frequently, nitride patches are marked by dark, smooth surfaces outlined by straight sides boundaries, which give the patch a definite

5. Rawdon, Groesbeck and Jordan—Technical Paper No. 179, Electric Arc Welding of Steel, Bureau of Standards, Washington.

6. B. Strauss, *Stahl und Eisen*, 1914, Vol. 34, part II, page 1814.

7. Comstock and Ruder, Effect of Nitrogen on Steel, *Chemical & Metallurgical Engineering*, Vol. 22, No. 9, 1920, page 401.

geometrical form quite in contrast to the rounded outline of ordinary pearlite.

In the specimens of boiler tube which were examined, the patches usually consisted of twisted chords which had been entangled into a confused mass. The shapes strongly resembled the irregular forms adopted when a film of water on a glass plate shrinks into pools as surface tension acts to reduce the surface area of the film. Indeed a similar effect occurs in the nitrogen bearing steels; the presence of the gas or its compounds prevents the formation of cementite lamellae and promotes the formation

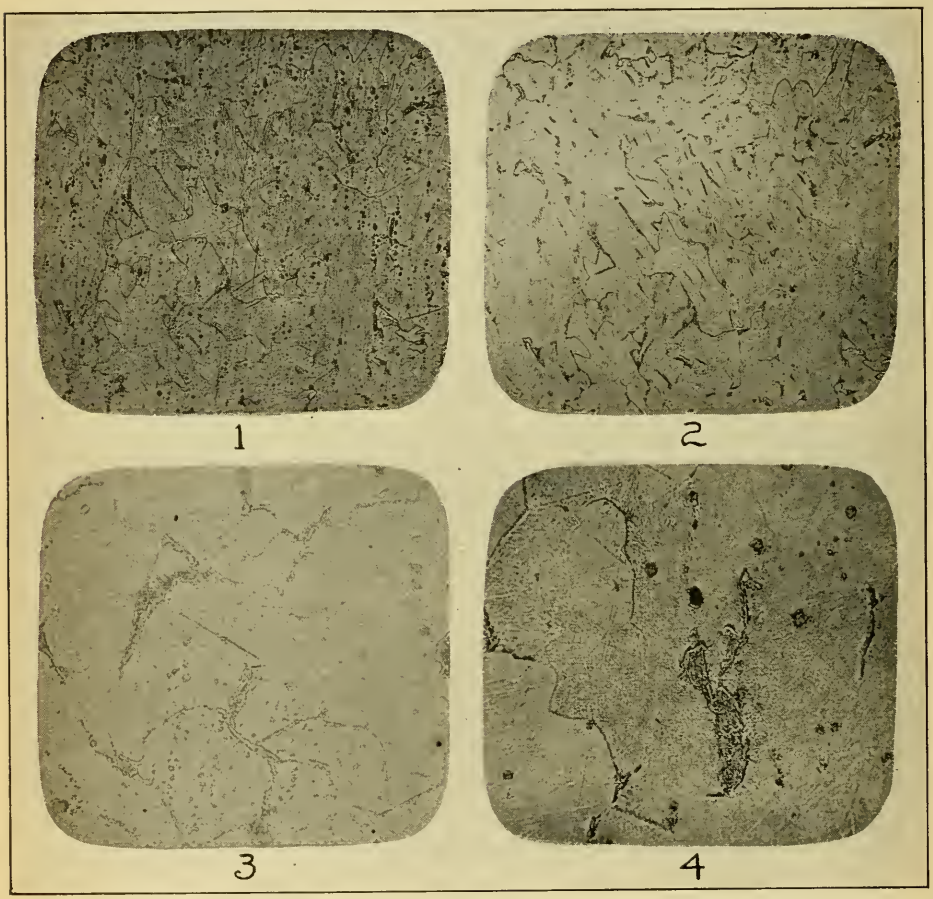


Fig. 1—Micrograph showing oxides in boiler tube steel. X 100. Fig. 2—Micrograph showing nitrides in the steel. X 100. In Figs. 1 and 2, the position of the oxides and nitrides with respect to the structure is intensified by a change in focus. The true image is distorted slightly. Fig. 3—A nitride patch X 500. Fig. 4—Another nitride patch X 500. Specimens shown in Figs. 1-4 were etched with a 2 per cent solution of nitric acid in alcohol.

of the tangled, coagulated chords. Thus the normal positions of the pearlite areas within the matrix is not appreciably altered but their internal structure is completely changed. The change within the nitride patches has been compared to the divorce of cementite in ordinary carbon steels. The conditions which encourage the change within the two types of steel are widely different. For example, the nitrogenized steels[8] are able to develop the di-

8. Note: A specific amount of carbon and nitrogen probably is necessary.

vorced type of structure with high heating and comparatively rapid cooling, whereas the usual cementite divorce requires a long sojourn at lower temperatures and a much slower rate of cooling. In addition, the ductility of carbon steels is usually improved by the cementite divorce.[9] Nitrogen-bearing steels which contain the divorced compound are inherently brittle.

The rapid coagulation of the compound within the nitride patches is indicative of the mobility of this constituent. This effect is partly demonstrated by the rounding of the edges of the nitride patches. The rounding of the edges and the graduation in color intensity from the edge to the interior of the nitride patch imposes the apparent relief effect and produces the brilliant edges that assist in distinguishing the nitrogen contaminated pearlitic patch from the carbon eutectoid pearlite.

The forms of nitride patch which occur in steel obviously may vary through any of the types described above. In specimens such as the boiler tube steel, several types occur within the same specimen. The composition, heat treatment and possibly, gas pressure exert an important influence upon the final structure.

An example of the peculiar forms of nitride compounds that may occur in a nitrogen-bearing steel is illustrated in Fig. 5. A precipitation of fine prismatic crystals has been deposited in a criss-cross manner, thus giving the deposit a trellis-shaped structure. The prismatic crystals possess more body than some of the individual nitride plates which may be traced in the micrograph, thus suggesting that the crystals represent the divorced or coalesced type of nitride. The crystals probably consist of an iron-carbon-nitrogen compound which is replacing what would normally have been a pearlitic area of the low carbon steel. The well developed form of the individual crystals would indicate that the compound possessed a prismatic crystal habit that is able to find expression because of the mobility of the compound. The prismatic crystal habit is also characteristic of cementite hence this observation does not assist in distinguishing the nitrogen compound from cementite. However, in low carbon steels which have been subjected to a divorce anneal, the coalesced cementite invariably is found to adopt a globular form.

In an effort to determine the part played by the oxides and nitrides upon the course of rupture, a fractured edge which contained tributary cracks, was polished and examined. Figs. 6, 7 and 8 illustrate the path of rupture adopted by several of these tributary cracks near the fracture surface. In Figs. 6 and 7, the fissures maintain their direction quite independently of the course of the oxide layers which traverse the surface at an angle of approximately 60 degrees to the fissures. Fig. 8 illustrates the appearance of the terminus of a larger crack in the metal. The prevailing direction of the crack has not been altered but its continuity has been repeatedly interrupted. The continuity of the rupture has been broken at the grain boundaries.

This course of rupture is quite in agreement with the characteristic paths of rupture followed in a steel that is free of such inclusions or compounds as the oxides or nitrides. Within certain grains a sharp change in the direction of the path of rupture has been enforced. The failure of the path to cleave the crystals in a straight line may be attributed to the specific internal structure of the individual crystals. The sharp changes in the course apparently are due to the obstructions raised by crystals, which by

9. Howe, The Metallography of Steel and Cast Iron, page 394.

virtue of an orientation that is unfavorable to the line of rupture, possess a greater resistance in that direction. For example, Fig. 8, shows the course of the crack sharply changed in crystal *a*. The directional change evidently is caused by the unfavorable orientation of the cleavage planes in the crystal, with respect to the prevailing path of rupture.

In describing the type of fracture that is frequently found in fusion welds, Miller has attributed its intercrystalline course to the presence of oxides at the grain boundaries. It would be reasonable to expect from the results of Miller's observations, that the impurity content of the weld was sufficiently great to invite intercrystalline rupture. The oxide and nitride inclusions in the boiler tube specimens, do not appear to be present in sufficient quantity nor located in sufficiently strategic positions to divert the path of rupture. The preference of the path of rupture for the crystal centers suggested that the inherent brittleness of the crystals themselves invited this course. The cleavage brittleness of the crystals is reflected in the comparatively straight fractures within each individual. Were the crystals possessed of the ductility of ordinary ferrite, the stresses set up in the rupture of the metal would strive to adjust themselves by the flow of the ductile crystals. However, no evidence of distortion or deformation is visible near the fracture. The brittleness of the individual crystals, appears to be responsible for the ultimate brittleness of the metal. The cleavage brittleness of the individual crystals suggests the presence of gases in solution.

Nitrogen and oxygen and their compounds may be introduced into steel in the melting or in subsequent heating operations. Manufacturing conditions may be concentrated into two physico-chemical problems which consist of a study of the temperature-concentration relations between the gas on one hand and the liquid and solid metal on the other.

In both cases, the metal can absorb or dissolve a definite amount of gas and upon cooling, retain a certain portion of the gas within itself either in solution or in the form of compounds. Practical examples of the gas-liquid metal problem are found in the refining of steel or in the manufacture of fusion welds. Examples of the gas-solid metal problem are evident in the nitrogenization of steel by ammonia, or furnace gases, and the oxidation of steel, or scaling. Unfortunately the problems are further complicated owing to the gases being most active when present in compound form such as air, ammonia or steam. Comparatively high temperatures usually are necessary before the reactions become rapid although the decomposition of air and the oxidation of steel become perceptible at 150 degrees Cent. at which temperature a polished surface is tinged with the pale yellow temper color. It is evident that iron or steel are capable of cracking air into its two principal components, oxygen and nitrogen. The scaling of steel surfaces upon heating is a common form of oxidation. A similar action occurs when ammonia is cracked by iron or steel into its components, nitrogen and hydrogen.

The large volume of nitrogen, or its compounds contained in waste gases resulting from the combustion of oil, gas or coal is known to penetrate the surface of metal exposed to it. A typical case of such contamination has recently been described by Blue[10]. Apparently high temperatures are necessary for this penetration. Below 650 degrees Cent. the influence of oxygen and nitrogen is limited to surface contamination. Above 650 degrees

10. *Iron Age*, Vol. 108, No. 1, page 1, July, 1921.

Cent. a solution and diffusion of nitrogen occurs and a similar behavior might be expected of oxygen.

Above the melting point of iron the quantity of gas soluble in the liquid metal reaches large proportions. When it is borne in mind that a

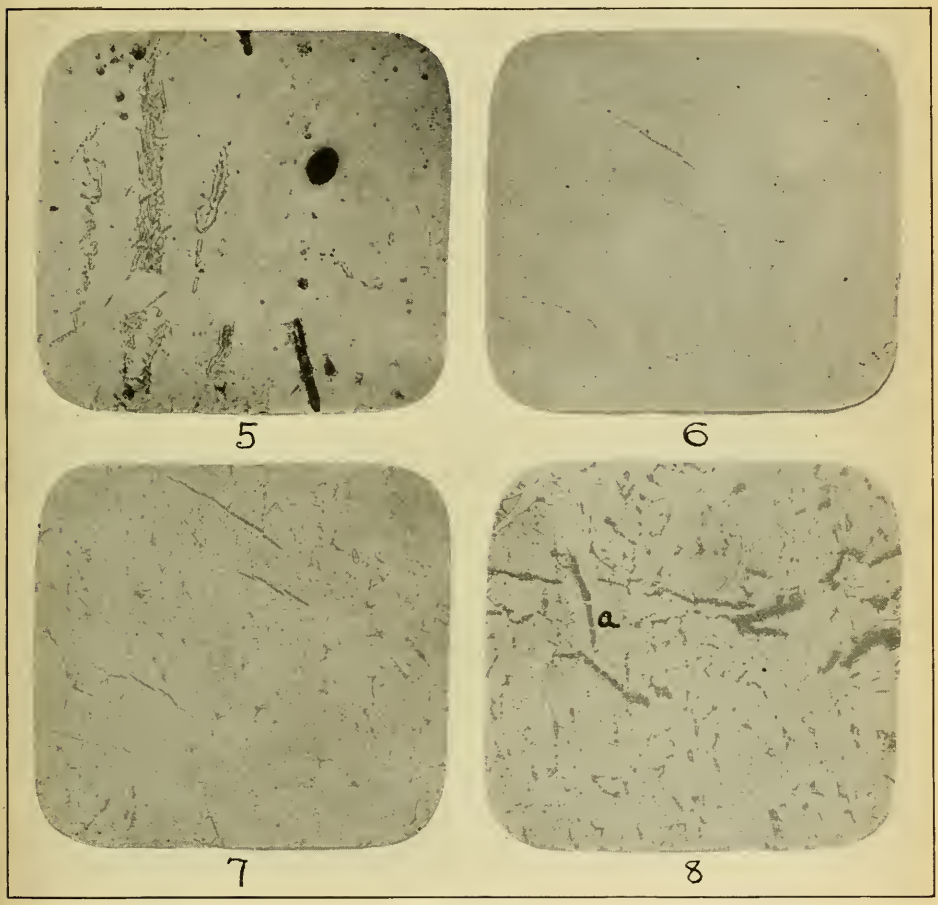


Fig. 5—A nitride patch in boiler tube steel, showing prysmatic type of nitrides. X 1000. Figs. 6-8 —Specimens illustrating prevailing transcrystalime course of rupture through the metal. X 100. Fig. 6 —Unetched surface showing minute fissures in fracture zone. Fig. 7—Surface shown in Fig. 6 after etching with a 2 per cent solution of nitric acid in alcohol. Fig. 8—Terminal of a tributary fissure from the fracture surface. Etched with a 2 per cent solution of nitric acid in alcohol.

unit volume of steel containing 0.1 per cent of nitrogen has dissolved roughly 6 volumes of the gas, the values become more impressive. The facts stated above, are mentioned for the purpose of calling attention to the need of further work upon the physico-chemical relations between metals and gases.

Since the equilibrium relations between oxygen, nitrogen and steel and the resulting mechanical properties have not been studied widely, the quantity limits within which the gases and their compounds are destructive to the properties of the metal, remain in doubt. Small quantities of dissolved nitrogen are known to produce brittleness in low carbon steel and carbon-free iron. Oxygen might be expected to affect the metals similarly.

The quantity of oxygen and nitrogen in the form of oxides and nitrides which may be present in iron and remain microscopically undetected, has not been thoroughly established. When available in the metallic solution in sufficient quantity to form microscopically visible compounds, a noticeable brittleness of the metal has been attributed to the presence of the gases or their compounds. Oxides repeatedly have been associated with the reasons explaining the brittleness of steels. The explanations have been particularly well grounded when the oxides could be identified as intercrystalline films or inclusions. Oxides which are distributed through the matrix have not been regarded with the same degree of suspicion unless they were present in excessive quantities.

The effect of nitrides upon the brittleness of steels is similarly interpreted in spite of the fact that the course of rupture has not expressed a tendency to follow the positions of the nitrogen compounds in the metal. It is known that nitrogen in solution, and therefore invisible, is capable of rendering the individual crystals brittle. The presence of nitrides and oxides in comparatively large colonies suggests that the metal contains the corresponding gases in solution, in a quantity that exceeds the limits of solution within which the influence of the gases is not detrimental. From the examination of the specimens of boiler tubing described, the nitrides and oxides micrographically illustrated in this paper; and the corresponding gases in solution, particularly nitrogen, are present in sufficient quantity to account for the brittleness of the metal. The particular course of the path of rupture suggests that nitrogen in solution, is the dominating cause of the brittleness.

CARBONIZATION WITH WOOD CHARCOAL

By H. Schagrin

IT WOULD be safe to say that ordinary wood charcoal alone, when considered in comparison with wood charcoal plus so-called energizers, is little used at the present time. Charcoal has been used and discarded by many hardening and carbonizing rooms but not always for the same reason. The experiments given in this article has been performed on a regular commercial scale to determine the carbonizing effect produced by the use of wood charcoal alone.

In the industry the action of absorption of carbon by steel when heated to the proper temperature for an hour or two in intimate contact with a carbonaceous material is known as case carbonizing, while the same process when extended over a considerable length of time, say a week or more, and where the pieces treated are large with consequent absorption of much carbon, is known as cementation. The former treatment, or case carbonizing using wood charcoal only, is the one under discussion in this article.

In general, to overcome the drawbacks encountered through possible brittleness, the practice of case hardening, or producing a high carbon case on a soft piece of steel is resorted to. There is room for argument and there is considerable diversity of opinion as to whether case hardening is the only recourse at all times, or whether the entire piece of higher carbon and sometimes plus alloys properly heat treated, would not serve the purpose equally well.

With proper treatment of a case carbonized piece after removal from the furnace, and with the elimination of the rather sharp line of demarcation between the high carbon case and low carbon interior, the result obtained is a piece of steel having the desired hard surface with a backing of soft, tough and malleable steel. In short, the latter will not stand wear or abrasion, since it is easily deformed, whereas the former is able to withstand the necessary wear and abrasion. The material used in these tests were drop forgings made from acid bessemer steel of composition approximately: Carbon, 0.15; manganese, 0.70; sulphur, 0.050; phosphorus, 0.060 per cent. The pieces were cheap and it is to be noted that the care and time expended in packing did not compare with that for pieces such as gears, which necessarily must be almost perfect.

For reasons given later, and explanation of the carbonizing action as understood, it was not deemed essential to take any special precautions as to mesh of the charcoal, although the material was a powdered mixture with pieces up to 30 mesh. Such precaution as observing that the carbonizing material was free from moisture was considered a routine one, but always should be strictly observed. The procedure followed was to place a layer of charcoal to a depth of one inch on the bottom of the carbonizing box, pack in one layer of forgings each about 12 inches long as closely as possible, cover with charcoal and see that there was no pockets by using a wooden ram; adding another layer of forgings and repeating until about even with the top. Charcoal was then heaped on top of the forgings, the cover pressed down, and the opening around the cover raised at times an inch from the box, and finally luted with a mixture of ordinary clay and water.

A paper presented at the Indianapolis Convention. The author, H. Schagrin is chief chemist, United States Naval Ordnance Plant, Charleston, W. Va.

After the boxes were removed from the furnace, it was often noticed that as much as one fourth of the charcoal had been burned, indicating considerable leakage of air into the box because of the cracking of the clay luting. Such condition can be remedied easily by the use of more modern appliances, for example, carbonizing boxes with grooved covers.

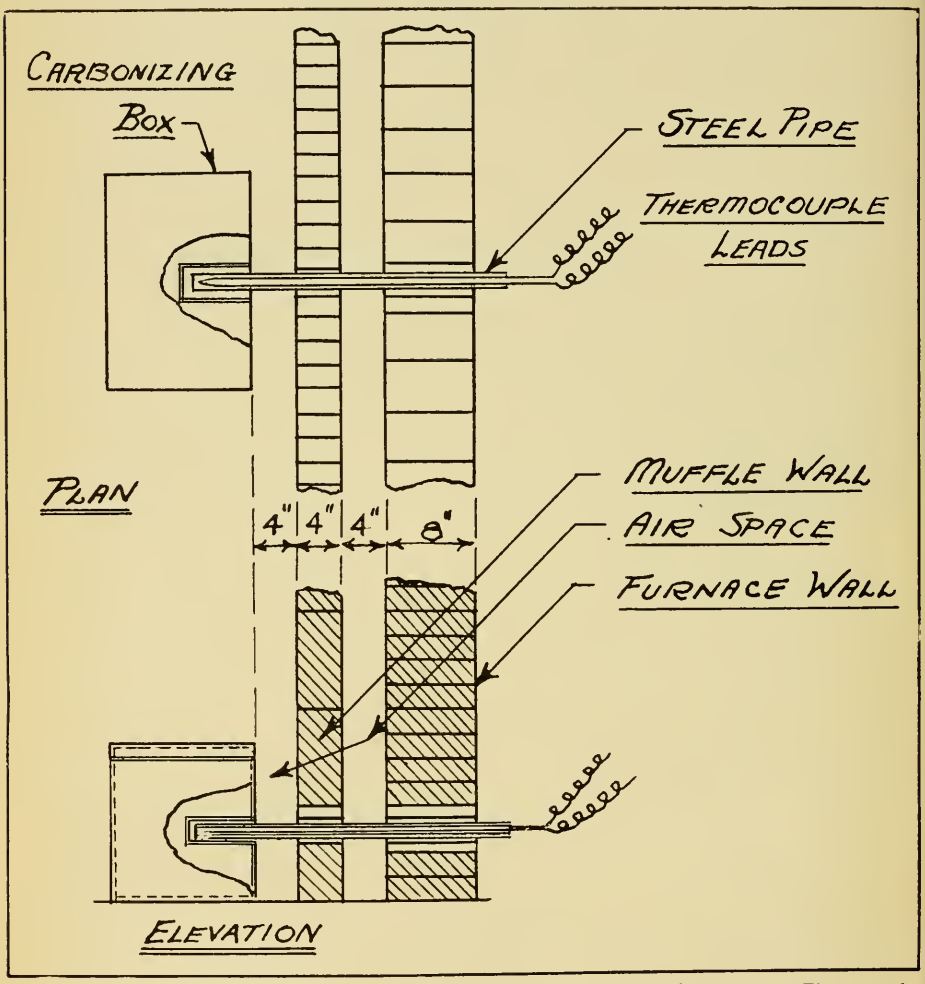


Fig. 1—Thermocouple arrangement used in the wood charcoal carbonizing process. Three couples were used in each furnace, each inserted in the carbonizing box as indicated.

In spite of production operations just outlined, the forging when allowed to cool in the boxes, then covers removed and the pieces taken out, showed a silvery color indicative of very little surface oxidation. The statement made above that a good portion of the charcoal had been consumed by air leakage, does not necessarily mean that the air came directly in contact with the pieces to be carbonized. The air, from the evidence at hand, must have combined with the charcoal to form the oxide gas carbon monoxide which we know is the real factor in carbonizing.

All up-to-date hardening rooms are now equipped with pyrometers.

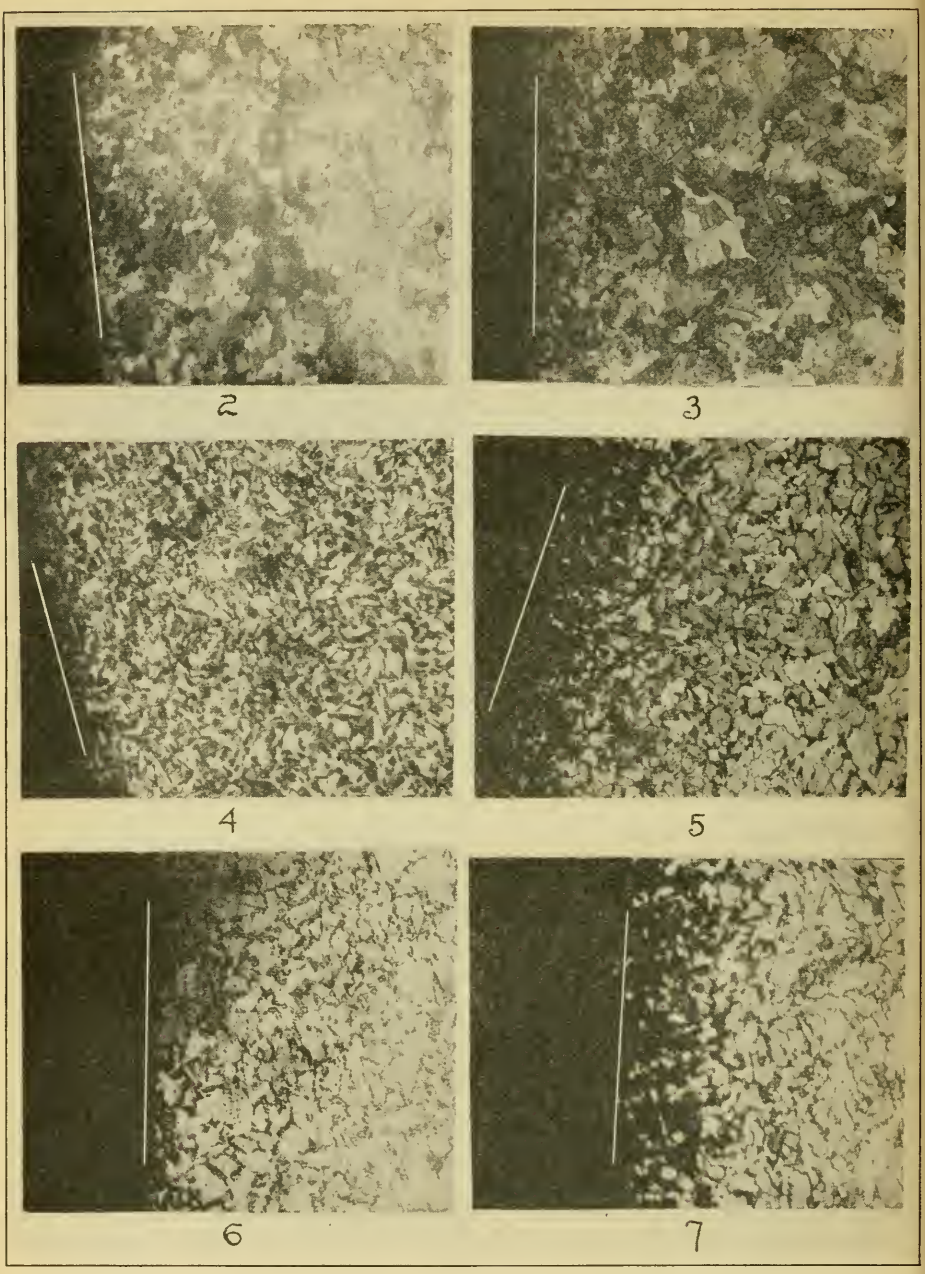
However, there are many that still depend upon the eye for temperature reading. In such cases, where failure of parts results, it is of course impossible to consistently trace trouble. There has been a great deal written on the proper placing of thermocouples in doing carbonizing work, and care as well as common sense must be exercised in maintaining a uniform temperature in a furnace where there are a number of burners. If the fuel be oil fed from a pump, care must be taken to see that the pulsating action of the pump does not have a direct effect upon the flame. During these experiments some trouble was caused by water in the fuel oil. If the fuel be gas, the proper precaution must be taken to see that the flow of gas is maintained at a constant pressure. The condition of the burners must also be such that the temperature can be regulated easily. The location of the burners are of equal importance.

The carbonizing boxes were all charged when the furnace was at a temperature about 300 degrees Fahr. The objects of the tests primarily were to determine the amount of penetration that takes place at 1400 to 1500 degrees Fahr. and at excessively high temperature, say 2000 degrees Fahr. Heat treatments are not discussed. Close control was kept at all times on the temperature of the pieces to be carbonized by having the fire end of the thermocouple set in the middle of the box. As an optical indication to the treater, a bar 4 x 4½ inches of the same steel as that being carbonized was inserted in the box in such a way that it could be withdrawn to note the color. This, however, was for the instruction of the furnacemen.

Other work with various kinds of carbonizing materials containing charred leather, powdered bone, charcoal and prussiates in varying proportions, has proven that absorption of carbon by the steel first takes place at about 1400 degrees Fahr., but to produce even a light case at this temperature would require a prohibitive length of time. The determining factors in carbonizing, when comparing the treatment of identical materials and using the same carbonizing compound, are time and temperature. Although it is evident that some carbonizing begins at 1400 degrees Fahr., the time of carbonizing properly should be considered from the time the work has reached the temperature desired.

The standard mixture of 60 parts charcoal and 40 parts barium carbonate intimately mixed gives good results, but is costly. The reaction claimed during carbonizing for this mixture, as forming carbon monoxide and cyanide of barium with the nitrogen of the air, seems less probable than the reaction by which carbon dioxide is released from the carbonate, the carbon dioxide reacting with the charcoal to give carbon monoxide. The next cycle will release oxygen as soon as absorption of carbon takes place, to form more carbon monoxide. The idea has also been advanced that the ash of wood containing alkali carbonates, would form alkali cyanides with the nitrogen of the air. This is doubted, as is the reaction above for the formation of the barium cyanide for the reason that the cyanides formed probably would have more decided effect than is actually the case.

To withstand bending stresses, it is not desirable to carbonize to more than 1.00 per cent carbon. Satisfactory results were obtained by maintaining the work at temperature of 1850 to 1900 degrees Fahr. for one hour. For production work, this allowed two charges per furnace for a working day of 10 hours. It was found that charcoal was a cheap and satisfactory casing material where a normal penetration of about



White lines appearing on these micrographs indicate edges of pieces. Fig. 2—Specimen carbonized at 1450 degrees Fahr. for 1½ hours. Quenched in water from box. X 100. Fig. 3—Specimen carbonized at 1450 degrees Fahr. for 1½ hours and cooled in furnace. X 100. Fig. 4—Specimen carbonized at 1500 degrees Fahr. for 1 hour and quenched in water from box. X 100. Fig. 5—Specimen carbonized at 1500 degrees Fahr. for 1 hour and cooled in furnace. X 100. Fig. 6—Specimen carbonized at 1550 degrees Fahr. for 1 hour and quenched in water from box. X 100. Fig. 7—Specimen at 1750 degrees Fahr. for 1 hour and cooled in furnace. X 100.

1/16 inch for about 1½ to 2 hours carbonizing period was desired. For periods over a greater length of time than indicated, other compounds must be present with the charcoal to cause a deeper penetration.

Discussion of Mr. Schagrin's Paper

MR. HILLMAN: I would like to ask Mr. Shagrin what kind of wood he would use?

MR. SCHAGRIN: This is a regular factory operation, and pieces all the way from forgings that weigh up to about ten pounds down to pins were carbonized. Therefore, I wouldn't want to say exactly what kind of charcoal it was. We had to use most everything at the time.

MR. HILLMAN: I have had some experience with carbonizing with wood, and the results were absolutely nil. Carbon heated in a furnace doesn't form dioxide very readily. I was always under the impression, and I believe that various authors substantiate my opinion, that in order to get the active vehicle, that is, carbon monoxide, you must have an energizer such as a carbonate. Carbon dioxide, which acts upon the carbon, forms carbon monoxide, which acts as the carbonizing agent. If you got carbonization with wood charcoal alone I think it is very probable that the particular type of wood that you used contained potassium salts, such as potassium carbonate, and they acted upon the carbon to form the carbon monoxide, which gave you the carbonizing action. Your paper is very interesting, indeed, and if you could prove by photomicrographs by measuring the depth of carbonization, that you have effected carbonizing action by means of wood charcoal alone, and that it can be repeated, I think it is a marked advance in science.

MR. SCHAGRIN: I would like to say this is a factory operation carried on on a tonnage basis and has been for years, at a certain plant, and for that reason, since it was a departure from every day practice, I thought the fact would be interesting. We use various kinds of wood, although some do have more alkali salts in the ash than others, but the facts remain, the results are produced. Nothing else is put in but the ordinary wood charcoal, so I am taking the results as the proof of the pudding.

MR. HILLMAN: You don't know one of the types of wood, do you?

MR. SCHAGRIN: Yes, we had some hickory and quite a lot of pine, but we used most everything, for the reason that we had to take what we could get at the time. I discussed in my paper why I believe the reaction that took place was started by whatever little air happened to be in the box, starting the reaction of oxygen plus the carbon in the wood ash to form carbon monoxide. That I believe would start the cycle.

MR. HILLMAN: What is the nature of your case after quenching? Is it martensitic?

MR. SCHAGRIN: The case was martensitic.

MR. HILLMAN: Isn't it a fact that you will obtain an extremely coarse core in carbonizing at such extremely high temperatures?

MR. SCHAGRIN: I have found from the results here that it is necessary to heat higher with wood charcoal to get the proper penetration. I had to go up to 1850 to 1900 degrees Fahr.

MR. HILLMAN: Don't you believe that high heating is bringing you back to the old cementation process?

MR. SCHAGRIN: That is the reason it has always been said

that heating with wood charcoal causes a coarse case, because it is necessary to heat it higher. But one point I wish to bring out again is that these were not special pieces and must be case hardened in a cheap way.

MR. HILLMAN: You quench in the box, then?

MR. SCHAGRIN: Yes, from the box.

MR. HILLMAN: What is the maximum depth of case that you obtained?

MR. SCHAGRIN: I have obtained slightly more than 1/16 inch.

MR. THUM: Could I ask the temperatures you are using in carbonizing in the process that you have just described?

MR. SCHAGRIN: Slightly over 1900 degrees Fahr. The furnace temperatures would run up as high as 1950 degrees Fahr. in the every-day work, because the men have so much to watch.

MR. THUM: I would like to point out that the process of cementation was used for a good many years in the cutlery trades with wood charcoal almost exclusively. They like to use charcoal only on account of the fact that they can depend on it. It is something that is uniform. Just as soon as they put burnt leather or other things in, they run into trouble. Also, it is well for everyone to be on the lookout in the reading of literature, and especially in interpreting results from commercial carburizers at the present time, due to the fact that nitrogen has a great influence on the carburizing process. It is difficult to distinguish the eutectoid produced by nitrogen and the eutectoid produced by carbon. They both have practically the same results in making a hard and brittle case. Consequently when you run into peculiar results in carburizing with leather, for instance, you have a case which is quite hard on quenching and yet if you analyze the outer edge you will find you have only 25 or 30 points of carbon, which is much too small to get the specific hardness which is desired.

CHAIRMAN HARTZELL: I would like to ask the gentleman who just spoke. In the cutlery business you use charcoal—you spoke of leather charcoal—have you tried the wood charcoal?

MR. THUM: Wood charcoal is what I meant to say.

MR. SCHAGRIN: In one particular case of hardening compound that I made an analysis of lately for very deep penetration, I found iron oxide—that is an every-day energizer, and I found carbonate of calcium, which is supposed to break up completely into carbon dioxide and calcium oxide at a lower temperature than carbonizing temperature. Some of those things which we consider impossible are sometimes found to be every-day results. We know that energizers are very good, but this happens to be a plant example of production work, and I thought the idea might be of some use to others.

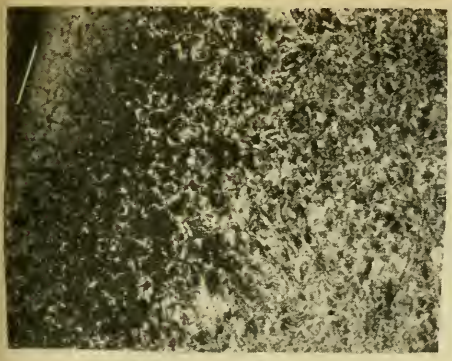
MR. HILLMAN: Can you re-use this compound?

MR. SCHAGRIN: No.

MR. HILLMAN: You cannot use it more than once?

MR. SCHAGRIN: Oh, yes, we take it out; it suffers a great deal of loss, but we do re-use it. The ash is so light that we depend almost on the ventilation of the room, the blowers and fans, to take the ash away, and shovel the rest of the material into the charcoal bin and use it over again.

MEMBER: I would like to ask Mr. Schagrin what he found was



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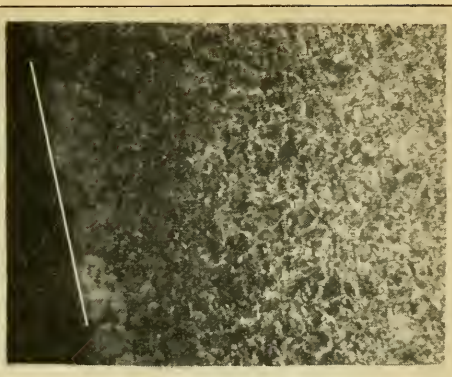

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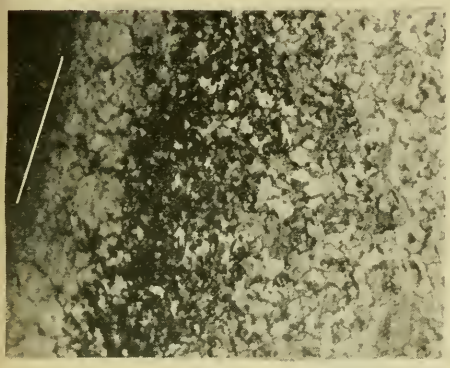

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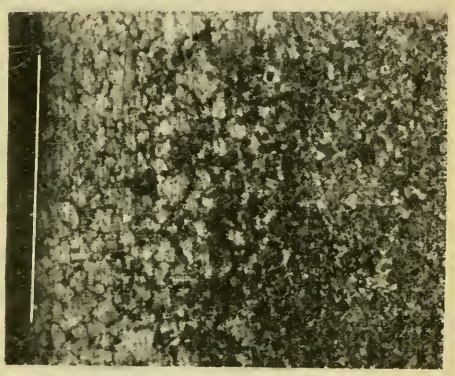

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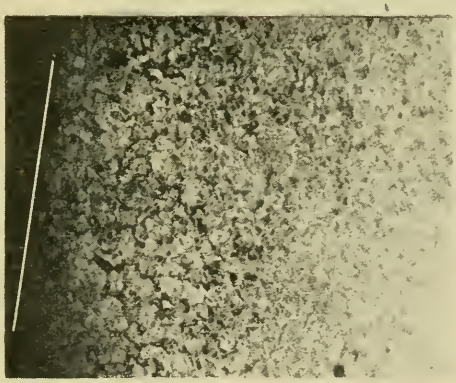

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White lines appearing on these micrographs indicate edges of pieces. Fig. 8—Specimen carbonized at 1900 degrees Fahr. for 1 hour, cooled in furnace, reheated, quenched in water from 1400 degrees Fahr. It shows surface decarbonization from reheating but the case is clear. X 100. Fig. 9—Specimen carbonized at 1900 degrees Fahr. for 1 hour, quenched in water from box, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100. Fig. 10—Specimen carbonized at 1900 degrees Fahr. for 1½ hours, cooled in furnace, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100. Fig. 11—Specimen carbonized at 1950 degrees Fahr. for 1 hour, cooled in furnace, reheated, and quenched in water from 1750 degrees Fahr. It shows surface decarbonization from reheating but the case is clear. X 100. Fig. 12—Specimen carbonized at 2000 degrees Fahr. for 1 hour, quenched in water from box, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100.

the carbon content of the hypereutectoid zone, using 1900 degrees Fahr. as the carbonizing temperature?

MR. SCHAGRIN: I think the highest carbon content we were in the habit of getting was slightly over 1.00 per cent, and we try to keep it a little under 1.00 per cent for the reasons stated.

MEMBER: Is the free cementite very pronounced?

MR. SCHAGRIN: When we went up to 2000 degrees Fahr. it was pronounced, but we had to go up to 2000 to get it pronounced.

MR. HILLMAN: Did you ever etch with sodium picrate and prove it was cementite?

MR. SCHAGRIN: Yes.

MR. NELSON: I think I might throw a little light on the question. I just left England in March, and I left there a battery of six cementation furnaces, and it was every-day practice to produce the old-fashioned blister steel. As I am presenting a paper tomorrow I can give you the depth of penetration of various millings from the outside to the center of the blister bar produced by the old-fashioned cementation process with the charcoal.

MR. HILLMAN: I am strictly in accord with the old cementation process, but if I speak correctly, it takes seven days, doesnt it?

MR. NELSON: It takes anywhere from 7 to 21 days.

MR. HILLMAN: This gentleman says that he can get carburization in one and one-half hours. How long does it take you to get your steel to the carburization temperature?

MR. SCHAGRIN: I would like to say that cementation takes place, but it must be remembered that this carburizing is done at a higher temperature than ordinarily. Ordinarily carburizing is not done at 2000 or 1900 degrees Fahr. Temperature is a very important factor in the absorption, regardless of what the carbonizing compound is. It took us usually between 1 and 1¼ hours.

MR. HILLMAN: That is with a cold furnace? In 1¼ hours your charge was heated up to 2000 degrees Fahr. then you continued carburization for 1½ hours?

MR. SCHAGRIN: No, where it took 1¼ hours the charge was placed in a hot furnace. A furnace that had recently been discharged, and it took 1¼ hours to bring the contents up. These experiments, however, were charged into a furnace at 300 degrees Fahr.

AUTOMATIC COMPENSATION FOR VARIATIONS IN TEMPERATURE OF COLD ENDS OF THERMOELECTRIC PYROMETERS

By William H. Bristol

FOR measuring high temperatures, such as are employed in the heat treatment of steel, the thermocouple has proved to be the most practical and extensively used device. Certain definite laws of nature govern the operation of the thermocouple. These laws or fundamental principles are for the most part simple. It is a well known fact that a thermoelectric couple made of two properly selected alloys will produce an electric current, the electromotive force of which depends upon the difference in temperatures between the two ends of the cupola, and consequently any variation of temperature of the cold end will change this electromotive force.

Ordinarily the hot junction of the couple is placed in the furnace

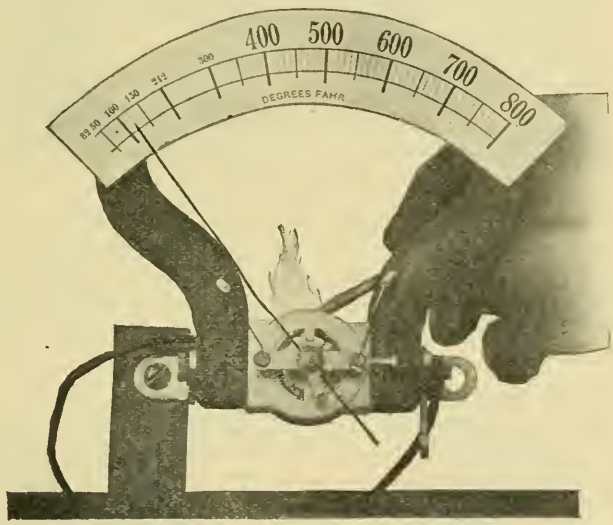

FIG. 1—INTERIOR VIEW OF OPERATING ELEMENT OF A PYROMETER SHOWING THE INDICATING ARM AND SCALE

where it is desired to measure the temperatures and the cold end is placed at some point where it is exposed to atmospheric temperatures. Variations of the electromotive force produced by the thermoelectric couple are indicated or recorded on the scale of a suitable electrical measuring instrument, calibrated in units of temperature.

To have the instrument give correct indications of the temperature at the hot end, it is evident that it will be necessary to either maintain a constant temperature at the cold end, or to provide means to compensate for changes of temperature at the cold end. Various methods have been tried for maintaining the cold end at a constant temperature,

A paper presented at the Indianapolis Convention. The author, William H. Bristol, is president, The Bristol Co., Waterbury, Conn. In absence of the author the paper was presented by H. L. Griggs, general sales manager, The Bristol Co.

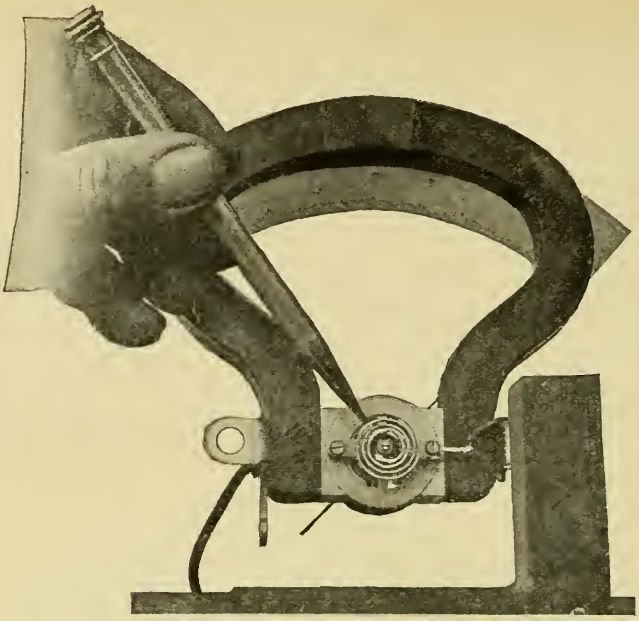

FIG. 2—A CLOSE VIEW OF THE COMPENSATING DEVICE IN THE PYROMETER INSTRUMENT

but under industrial and commercial conditions, there is a great need for making the pyrometer automatically self compensating, regardless of

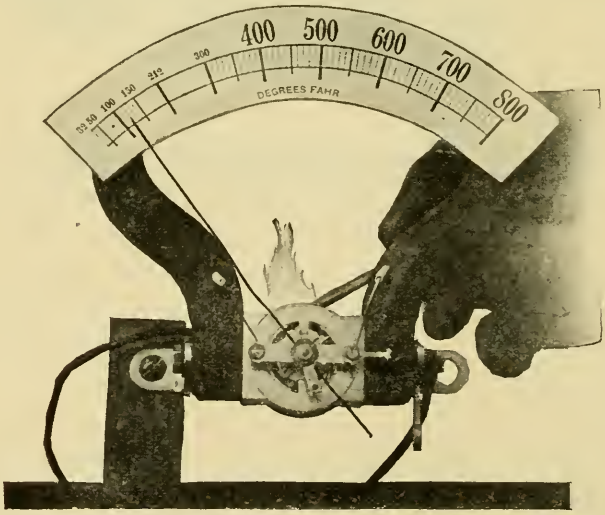

FIG. 3—EFFECT OF A LIGHTED MATCH ON COMPENSATING SPIRAL AND INDICATING ARM

atmospheric changes of temperature which may take place from time to time.

Since the electromotive force upon which the measuring instrument depends for its operation is a function of the difference of temperature between the hot and cold ends of the thermoelectric couple, it will be seen readily that errors will be indicated on the measuring instrument if the cold end temperature varies, and these errors will be equal approximately to the amount of such variations.

By way of illustration suppose the temperature of the hot end in a furnace is 1500 degrees Fahr. and the cold end of the couple exposed to room temperature is at 75 degrees Fahr. If the room temperature should rise from 75 to 125 degrees while there was no change of the temperature of the hot end in the furnace, the difference of temperature between

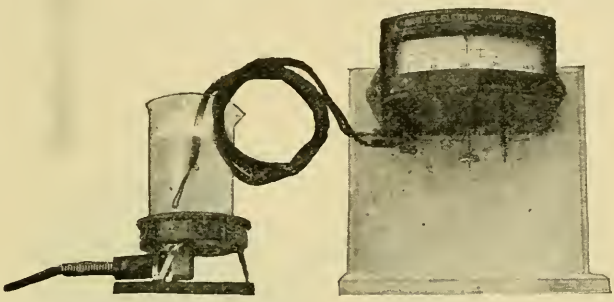

FIG. 4—A COMPLETE COMPENSATING INSTRUMENT ASSEMBLED AND READY FOR USE

the hot and cold end before the rise would have been 1425 degrees Fahr., while after the rise in the room temperature, this difference would be reduced from 1425 to 1375 degrees Fahr. This latter difference would generate less electromotive force and consequently there would be a reading on the instrument below the true reading corresponding to 50 degrees, independent of the type of electrical measuring instrument.

Should the temperature of the room fall, the difference of temperature between the hot and cold ends would be increased and a greater electromotive force would be generated, producing a reading which would be too high. Such errors as these are often caused by the neglect or oversight of this fundamental principle of the thermoelectric couple.

By the aid of several illustrations it will be shown that when the automatic cold end compensator is used in a pyrometer made by The Bristol Co., Waterbury, Conn., the temperature of the cold end may vary over a range of 100 degrees Fahr., but the reading on the instrument still will be correct. To give a clear idea of the compensating device, the author will show how it is made and mechanically applied to the moving element of the electrical measuring instrument.

Fig. 1 is an interior view of the operating element of a pyrometer, showing the indicating arm and scale. When the instrument is turned around, the automatic compensating device can be seen to consist of a bimetallic coil or spiral as shown in Fig. 2. The inner end of this spiral is fastened rigidly to the frame and the outer end connects to the free end of the control spring. It will be evident that any change of temper-

ature to which this measuring element is exposed will cause the compensating spiral to wind up or unwind in proportion to the temperature changes, and thereby mechanically to move the indicating arm up or down the scale in the same proportion, quite independent of any thermocouple or current flowing through the instrument.

Operation of the compensating spiral when subjected to temperature changes, as for instance when heat is applied with a lighted match held near it is that the indicating arm moves upward on the scale, as shown in Fig. 3. When the match is removed, the pointer will return to its original position on the indicating scale. From this it will be seen that the indicating pointer takes a position on the scale corresponding to the temperature of the bimetallic compensating spiral.

If we now use a complete pyrometer measuring instrument provided with bimetallic compensating spiral, and if the thermocouple used for

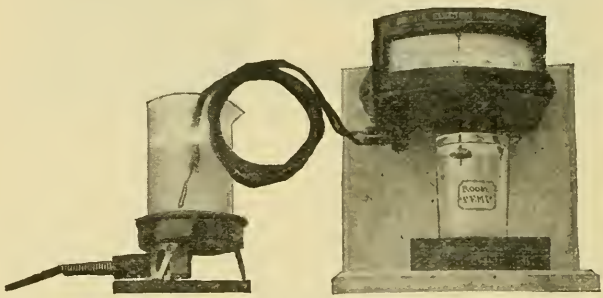

FIG. 5—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR BOTH IMMERSED IN WATER AT ROOM TEMPERATURE

measuring temperature is extended so as to reach inside of the instrument, it is evident that any change of room temperature that occurs will raise or lower the temperature of the whole instrument, including the enclosed cold end of the thermocouple, and the bimetallic compensating spiral. The resultant effect on the complete instrument when in operation is that the cold end temperature errors will be corrected for.

To make it convenient to apply different temperatures quickly to both compensator and the cold end, which are usually located within the instrument, and to make it possible to show the effects of these various changes, a complete instrument is shown in Fig. 4. Two holes have been drilled in the bottom of the case of this instrument, and both compensating spiral and the cold end of the thermocouple have been brought out through these holes on the lower side of the case, and located so that temperature of either one can be raised or lowered independently of the

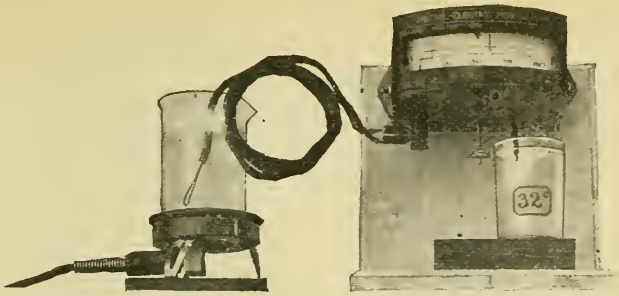

FIG. 6—HOT END IMMERSED IN BOILING WATER AND COLD END IMMERSED IN ICE WATER

other, and so that both can be subjected to the same temperature conveniently by the use of vessels of water at different temperatures.

The hot end of the flexible thermoelectric couple is immersed in a glass of boiling water and is maintained at a temperature of 212 degrees Fahr. on an electrical heater, as is shown by the indicating pointer in Fig. 4 . When the hot end of the couple is removed from the water, the indicating pointer immediately indicates the fall in the temperature and upon returning the hot end to the water, the reading on the instrument immediately will be brought back to its original point on the scale, 212 degrees Fahr., that of the boiling water.

During the experiments with the compensating device and the cold end of the thermocouple, the hot end will remain in the boiling water, which will be maintained constantly at 212 degrees Fahr. so that all variations and experiments upon the cold end and compensator will be quite independent of any changes at the hot end of the thermocouple, thus

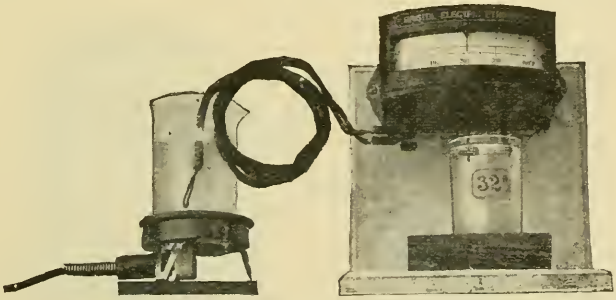

FIG. 7—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR IMMERSED IN ICE WATER

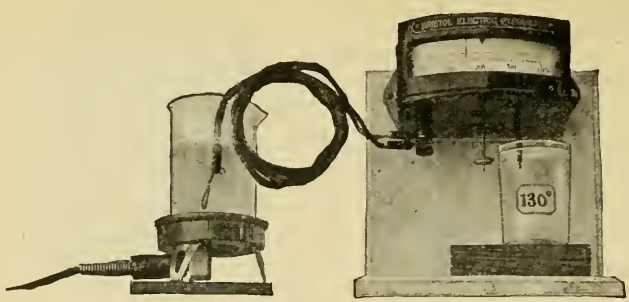

FIG. 8—HOT END IMMERSED IN BOILING WATER AND COLD END IMMERSED IN WATER AT 130 DEGREES FAHR.

making it a simple matter to observe readily the operation of the compensating device and effect of temperature changes that are applied to the cold end of the couple.

To demonstrate that the temperature of the cold end of the thermocouple and the compensator are at exactly the same temperature as they would be normally when inside of the instrument, they will both be immersed in a glass of water at room temperature, which causes no change in the reading on the instrument, as shown in Fig. 5. The temperature of the cold end will then be lowered to 32 degrees Fahr. by immersing it in a glass of ice water, as shown in Fig. 6, and the indicating arm will move up the scale showing an error due to the cooling of the cold end to 32 degrees Fahr.

In Fig. 7, both the cold end and the compensator are immersed in the glass of 32 degrees Fahr. ice water and the indicating pointer on the instrument will return instantly to its original correct position 212 de-

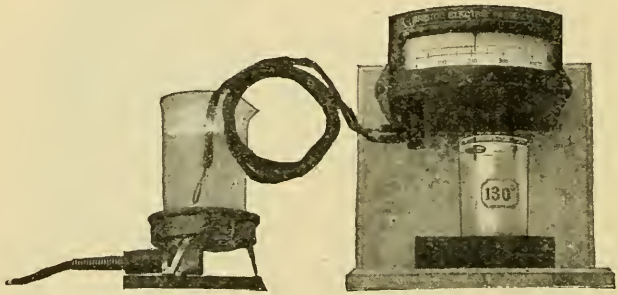

FIG. 9—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR IMMERSED IN WATER AT 130 DEGREES FAHR.

grees Fahr. on scale, showing that the cold end temperature is eliminated when both cold end and compensator are lowered in temperature.

Having shown that the error caused by lowering the temperature of the cold end when no compensation is provided and how the error is automatically compensated for, we will now show the effect of raising the temperature of the cold end. In Fig. 8 the cold end is shown immersed in a glass of water at 130 degrees Fahr. and the indicating pointer moves down the scale, showing the error due to heating the cold end alone to 130 degrees Fahr. In Fig. 9 both the cold end and the compensator are immersed in the glass of water at 130 degrees Fahr. and the indicating pointer will immediately return to its original correct position of 212 degrees Fahr. on the scale, showing that the cold end temperature error is eliminated when both the cold end and the compensator are raised in temperature.

Thus it will be noted that the effect of the automatic cold end spiral is to neutralize the errors caused by variations of temperature of the cold end of the thermocouple, and that it automatically compensates for atmospheric changes in temperature from 32 to 130 degrees Fahr. Both the cold end of the thermocouple and the compensator are located within the instrument and in practice they are both subjected to the same rise or fall of the room temperature, and the instrument will therefore show the true temperature independent of any atmospheric temperature changes where the instrument is located.

This method of automatically compensating avoids the necessity of making corrections or employing expensive and complicated devices for artificially holding the cold end of the thermocouple at a constant temperature. This compensator can be applied readily to millivoltmeter types and all ranges of thermoelectric pyrometers, either indicating, recording or controlling, to secure accurate results even under difficult conditions ordinarily found in industrial plants. Many of these instruments have been equipped with this compensator and put into successful service.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

REPORTED FROM THE ROCKFORD CHAPTER

QUESTION NO. 1 Has anyone present at this meeting had any experience demonstrating the beneficial influence of heat treating in connection with automobile and similar parts compared with untreated alloy steel?

ANSWER. By Charles Cotta of the Cotta Gear Co., Rockford, Ill. The drive shaft in a 5-ton truck measuring about 2⅛-inch in diameter gave satisfactory service for an indefinite period. When it was changed to a 7-ton truck the change made it necessary to reduce the cross section of the shaft by about ⅛ inch. The shaft failed after a short period of service, and when the causes of the failure were investigated, it was found that the material used was a 3½ per cent nickel steel untreated. The description of this material answered S.A.E. Specification 2335. In this instance, as is well known, the material has an ultimate strength of about 50,000 pounds per square inch. If this material had been heat treated its physical properties would have been as high, which would have provided a large margin of safety, the reduction in diameter notwithstanding. Events later on proved this assumption to be correct.

QUESTION NO. 2. What are the respective merits of carbonizing under high heat for a short time or low heat for a long time, and why is sometimes one employed and why the other?

ANSWER. By R. M. Smith, Mechanics Machine Co., Rockford, Ill. The advantage of high carbonizing heat is that it is a time saver. Its disadvantages are: Increased cost of maintenance for furnaces, coarsening of the structure of the parts being carbonized, and inferior wearing qualities in the case thus obtained. Where no other requirements than mere hardness are to be met, higher heats, such as above 1700 degrees Fahr. are permissible and from a production standpoint perhaps warranted, but never recommended by the conscientious heat treater. Lower temperatures will require longer time and are in consequence more expensive for obtaining a case of equal thickness. However, in employing lower temperature the carbon contents of the case shades gradually into the core, and in consequence a case of a much higher wearing quality is obtained. Further, it has been observed that the case from lower carbonizing temperatures, that is from 1600 to 1700 degrees Fahr., shows less tendency to separate from the core underneath.

QUESTION NO. 3. Why do green castings warp during and after machining, and what can be done to overcome it?

ANSWER. By C. Craine, Mattison Machine Works, Rockford, Ill. During the war large numbers of fixtures and gages with cast iron bases

or frames were made which had to be turned out hurriedly and therefore could not be given the customary ageing, which consists of exposing them to the open air under varying weather conditions from six months to one year. We noticed considerable warpage during and after machining and remedied this disturbance by placing the castings, which were of the regular gray iron type, into a furnace, maintaining a temperature varying from 600 to 900 degrees Fahr. for a period of 12 to 18 hours and cooling them with the furnace. In most cases this procedure was sufficient to overcome the trouble. During further machining operations this was found not to be the case so a second treatment of the same temperature and equal time was applied, for example, from 12 to 24 hours was added. In extreme cases when even two treatments did not prove sufficient, the castings were hammered and exposed for a third time to a temperature from 600 to 900 degrees Fahr. and a similar period of time as before. This did away entirely with all distortion and I am unable to relate one case where further disturbance or changes in the finished gage were observed.

QUESTION NO. 4. One more question was asked pertaining to the rehardening of a die and a result of very short life, the ratio being about 10 to 1 compared with the first hardening. Several explanations were offered: 1. Insufficient annealing previous to hardening; 2. insufficient removal of stock from the old surface; 3. insufficient allowance of room around the form for flash; and 4. improper hardening. For proper hardening the suggestion was made to place the die block into the furnace, running at a temperature of 500 degrees Fahr. and then to allow one hour of time for every inch of thickness of the block until it was heated to 1500 degrees Fahr. For instance, if the die measures 7 inches high by 10 inches wide by 16 inches long, the total time for reaching the hardening temperature would be seven hours. An addition of two hours should be made for equalizing the temperature throughout, so that the total time of being in the furnace and previous to quenching would be nine hours. As proof for the correctness of this method, the experience of a large drop forging department was related to the effect that out of about one thousand die blocks only three were lost on account of cracking.

QUESTION NO. 5. *What is needle bar stock?*

QUESTION NO. 6. *Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest
to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

NITROGEN IN CARBURIZED STEELS. By W. E. Ruder and G. R. Brophy, *Chemical and Metallurgical Engineering*, Vol. 25, Page 867.

Nitrogen as well as carbon is responsible for the hardening obtained on carbonizing. Nitrogen may be detected by the use of Stead's reagent. The effect of nitrogenous and nitrogen-free carbonizers on pure iron was investigated as was the effect of nitrogenous carbonizers on all of the common alloy steels. Nitrogen was found to act similarly to carbon. No actual nitrogen determinations were made, the results all being based on metallographic inspection.

EFFECT OF HEAT TREATMENT ON PHYSICAL PROPERTIES

ARTIFICIAL SEASONING OF STEELS. By H. J. French, *American Machinist*, Vol. 55, Page 768.

It has been known for some time that steel after certain heat treatments underwent dimensional and thermal changes at room temperatures. Little quantitative data, however, is at present available. Experiments were undertaken at the Bureau of Standards on five classes of steels, including, carbon, chrome and manganese steels. The steels were made up into gage blocks given various heat treatments and finished, after which they were tested at definite time intervals for dimensional and hardness changes. The results are presented in tabular form. Th high chrome and the plain carbon steels were found to be unsatisfactory as gage material. An adequate theory explaining the dimensional and thermal changes is as yet wanting.

A BIBLIOGRAPHY AND ABSTRACTS OF CHROMIUM STEELS. By F. P. Zimmerli, *Chemical and Metallurgical Engineering*, Vol 25, Page 837.

The principal papers on chromium and chromium alloy steels published during the period 1798 to 1919 are given with a brief summary of their scope.

A STUDY OF IMPACT TESTS ON CAST STEEL. By F. C. Langenburg, *The Iron Trade Review*, Vol. LXIX, Page 1145.

The influence of varying amounts of phosphorus, carbon and manganese and the influence of varying heat treatments on the Charpy impact value and on the tensile properties of steel were studied. From the tests it may be concluded that (a) varying the phosphorus from 0.043 to 0.075 per cent has little effect on the tensile properties but reduces the Charpy impact value by over 50 per cent; (b) keeping the carbon below 0.30 per cent and the manganese below 1.30 per cent appreciably increases the impact value; and (c) water quenching steel castings noticeably improves the impact resisting qualities. For the sake of comparison a table is given showing the effect on the tensile properties and Charpy values of forged steel obtained by varying the composition and the heat treatment of this stock.

IMPACT PROPERTIES OF VARIOUS STEELS. By F. C. Langenburg, *Chemical and Metallurgical Engineering*, Vol. 25, Page 910.

A study of the Charpy values obtained on centrifugally cast steel cylinders is described in detail. The other data given is the same as that covered in the article appearing in *The Iron Trade Review*.

ENAMELED STEEL

ENAMEL STEEL MANUFACTURE. By C. H. Jones, *Chemical and Metallurgical Engineering*, Vol. 25, Page 883.

A description of the plant and equipment of the Pfaudler Co., Rochester, N. Y., is given.

ENAMEL-LINED APPARATUS. By C. H. Jones, *Chemical and Metallurgical Engineering,* Vol. 25, Page 927.

A description of the plant and products of the Elyria Enamel Products Co., Elyria, O., is given.

MAGNETIC TESTING

MAGNETIC SURVEYS OF RAILROAD RAILS, Anonymous, *Iron Age,* Vol. 108, Page 1271.

Little that is new has been developed since the publication of Dr. P. H. Dudley's paper before the American Society for Testing Materials two years ago. It has been found possible to differentiate positively between ductile and brittle rails. The beneficial effect of reheating before the final rolling of the rail has been demonstrated. Many magnetically tested rails have been put in service, but it is yet to early to draw any conclusions from their performance.

MAGNETIC ANALYSIS OF STEEL. By R. L. Sanford, *American Machinist,* Vol. 55, Page 836.

A brief description of the fundamental principles underlying magnetic testing is given and some of the outfits used are shown. Attention is called to the fact that if a specimen is mechanically nonuniform, magnetic nonuniformity will always be found but that magnetic nonuniformity does not always indicate mechanical nonuniformity. Considerable additional research is still necessary before this method of testing may be generally applied.

METALLOGRAPHY AND HARDNESS THEORY

CONTRAST ETCHING FOR METALLOGRAPHIC SPECIMENS. By H. S. Rawdon and Marjorie G. Lorentz, *Chemical and Metallurgical Engigneering,* Vol. 25, Page 915.

The use of hydrogen sulphide followed by silver nitrate as a contrast etch for brasses and bronzes is described. In some bronzes it was found advantageous to use the silver nitrate first and then the hydrogen sulphide. Several photomicrographs are shown.

METALLOGRAPHIC TESTING. Bureau of Standards, Circular 42, 2nd Edition.

The circular discusses briefly the conditions which affect the properties of metals under the following divisions: Microscopy and structure, thermal analysis and heat treatment, mechanical working of metals, chemical and metallurgical factors and melting conditions. The conditions under which metallographic tests are made at the Bureau of Standards are explained.

THE ORIGIN OF STRAINS IN HEAT TREATING. By W. Tafel, *Stahl und Eisen,* Vol. 41, Page 1321.

The volume changes taking place on heating and cooling steel as various roles are followed. The opinions of the author and of Heyn on the causes of hardening are set forth. No original data is given.

THE STUCTURE AND RELATED PROPERTIES OF METALS. Bureau of Standards, Circular 113.

This circular supplements the one on "Metallographic Testing." The development of structure in alloys is first discussed and a list of etching reagents is given together with information on their purpose and use. The effect of composition on structure is considered. The changes due to changes in composition, heat treatment, etc., are discussed. The effect of structure on the physical and chemical properties is covered and typical applications of the miscroscopic study of metals are cited.

NEW MATERIALS

THE FUTURE OF STAINLESS STEEL, Anonymous, *Engineering,* Vol. CXXXII, Page 447.

The use of high chromium steel as turbine blades and pump rams is discussed.

GENELITE: AN IMPROVED BEARING ALLOY. By E. G. Gilson, *General Electric Review,* Vol. XXIV, Page 949.

A new bearing material is described having a compressive strength of 50,000 pounds

per square inch. It is made up of bronze containing many fine particles of graphite. Bearings are made up from the powdered bronze by pressure.

WELDING

THE SCIENCE OF ELECTRIC WELDING. By W. E. Ruder, *Journal of the Franklin Institute,* Vol. 192, Page 561.

A discussion of the rise and development of welding is given. The various types of welds are taken up and the structure of the finished welds is shown by numerous photomicrographs. Equipment is discussed in very general terms. The article is of a nontechnical nature and no new data is submitted.

WELDING IN THE DROP FORGE SHOP. By J. H. G. William, *Forging and Heat Treating,* Vol. 7, Page 453.

This paper is restricted to the electric resistance method of welding by which two pieces of metal are held together while an electric current is passed through them sufficient to develop heat enough at their point of contact to produce fusion. Welds were made on a large number of ¼ and ⅜-inch round stock. The physical properties of these welded rods were determined and are presented in tables. In no case was the strength of the weld less than one-third of the strength of the stock.

THE FUSION WELDING OF STEEL. By S. W. Miller, presented at the November meeting of the American Iron and Steel Institute.

Three types of fusion welding are at present in use, (a) gas welding, (b) arc welding, and (c) thermit welding. The present paper is confined to the two former types. Low carbon steel rods (carbon 0.05 to 0.16 per cent) are used for filling in the weld and in the case of the arc weld it has been found advantageous to use rods covered with a slag forming material. Nickel steel welding rods have been found to be superior to the plain carbon steel rods. Welds are to a large extent dependent upon the skill of the welder. The welder should be given proper training and his work should be tested at regular intervals. Welds are in general weak to shock and alternating stresses and the tests used are described. A considerable amount of research is still needed before great uniformity may be expected in welded material.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

BARBER-COLEMAN CO., (M-11), Rockford, Ill.
CASEY, F., (M-10), Madison Ave., Hartford, Conn.
COALE, L. N., (M-12), 15416 Loomis, Ave., Harvey, Ill.
FREDERICK, JOHN B., (M-11), 425 Oakley Ave., Rockford, Ill.
FULTON, WILLIAM, (M-12), 1259 E. 134th St., Cleveland, O.
GORRELL, JAS. T., (M-11), R. F. D. No. 1, Rockford, Ill.
GULICK, LEE NELSON, (M-11) 334 W. Logan St., Philadelphia, Pa.
GREENSLIT, E. M., (M-11), 319 N. Day Ave., Rockford, Ill.
GROTTS, FRED, (M-12), Holt Mfg. Co., Peoria, Ill.
HARBERT, W. G., (M-12), 207 W. Webster Ave., Muskegon, Mich.
HARRISON, O. H., (M-11), 612 Fifteenth St., Rockford, Ill.
HEURING, H. T., (M-12), 1005 First St., Charleston, W. Va.
HICKOX, WILL, (M-11), 1015 Tenth Ave., Rockford, Ill.
HINER, W. F., (M-11), 15200 Turlington Ave., Harvey, Ill.
HOERLE, WILLIAM F., (M-10), Union Hardware Co., Torrington, Conn.
HUGHES, FREDERICK G., (M-12), New Departure Mfg. Co., Bristol, Conn.
JACKMAN, ALAN, (M-11), Missouri Athletic Assn., St. Louis, Mo.
JOHNSON, F. ELMER, (M-11), 15805 Lexington Ave., Harvey, Ill.
KNAPP, EDWIN, (M-11), 209 So. Independence Ave., Rockford, Ill.
KUNZE, GEO W., (M-11), 207 Van Alstyne Bldg., Wyandotte, Mich.
LAKE, E. F., (M-12), 2115 Vinewood Ave., Detroit, Mich.
MACKENZIE, FRANKLIN H., (M-11), Norton Co., Worcester, Mass.
MATHER, CHAS. E., (M-11), Sixth and Boymiller Sts., Cincinnati, O.
McKEE, J. H., (M-11), 79 W. 150th St., Harvey, Ill.
MEMERING, A. H., (M-11), E. B. Company, Rockford, Ill.
MORANTY, ADAM F., (M-11), 3938 Livernais Ave., Detroit, Mich.
MORRISON, HARRY J., (M-11), 831 McCartney St., Easton, Pa.
NASH, GEO. CO., 1616 Harlem Rd., Rockford, Ill.
NELSON JOHN A., (M-11), R. R. No. 9, Rockford, Ill.
NICHOLS, W. HART JR., (M-12), 44 Woerd Ave., Waltham, Mass.
OLSON, OTTO H., (M-11), 1044 E. State St., Rockford, Ill.
PALMER, FRANK R., (M-12), 128 N. Spring St., Reading, Pa.
PIERCE, HAROLD M., (M-12), 1723 Lafayette Blvd., Detroit, Mich.
RABB, F. C., (M-11), 324 Gordon Ave., Syracuse, N. Y.
SCHWARTZ, HARRY A., (M-12), 10600 Quincy Ave., Cleveland, O.
SHAW, G. M., (M-12), 642 Munsey Bldg., Washington, D. C.
SMITH, ALAN WOOD, (M-12), Cohoes Rolling Mill Co., Cohoes, N. Y.
STEPHEN, G. E., (M-12), 286 Main St., Worcester, Mass.
THURSTON, CONIE M., (M-12), Simonds Mfg. Co., Fitchburg, Mass.
U. S. BUREAU OF MINES, (Sb.-1), Morse, Hall, Ithaca, N. Y.
VLCHECK, HENRY, (M-12), Vlcheck Tool, 3000 E. 87th St., Cleveland, O.
WARD, H. IRVING JR., (M-11), 544 Seymour St., Syracuse, N. Y.
WARING, F. M., (M-11), Pennsylvania System, Altoona, Pa.
WATTS, ARTHUR F., (M-11), 236 E. 32nd St., Paterson, N. J.
WESTERN ELECTRIC CO., (Sb-1), Engineering Library, 263 West St., New York City.

CHANGES OF ADDRESS

BECKER, G. H.—from 1521 Ardmore Ave. to 4911 N. Leavitt St., Ravenwood Station, Chicago, Ill.
BURKHARDT, D.—from 823 E. Donald St., South Bend, Ind. to 117 E. Mishawaka Ave., Mishawaka, Ind.
BUSH, A. T.—from 1115 Quarrier St. to 1414 Kanawha, Charleston, W. Va.
CHABOT, J. M. F—from 30 Orchard St, Bristol, Conn. to 85 Dwight St., New Britain, Conn.
CHURCH, HARLOW—from 165 N. Pine Ave. to 524 North Leeland Ave., Chicago.
COPELAND, C. W.—from Timken-Detroit Axle Co. to Rickenbacker Motor Co., Detroit.

DOBBS, L. D., (M-11)—from Minneapolis Bedding Co. to 616 12th Ave. S. E. Minneapolis, Minn.
GUSTAFSON, R.—from 2827 S. Mich. Ave., Chicago to 2815 13th Ave., Moline, Ill.
GARDINER, F. E.—from 222 Crafton St., Charlottetown, P. E. to Crucible Steel Co. of America, 163-5 Richmond St., W. Toronto, Can.
GEISSLER, W. E.—from 17 James St. Holyoke, Mass. to Columbus St. Greenfield, Mass.
HAWKINS, E. R., (M-4)—from Y. M. C. A. to 724 Delaware St., Gary, Ind.
HAWLEY, PHILIP, (A-12)—from Box 166 to Box 158, Torrington, Conn.
HAYNES, J. K., (M-7)—from 18 West St., Waterloo, N. Y. to The Engineering Experiment Station, Annapolis, Md.
HUMMELL, A. S.—from Wm. Wharton Jr. & Co., Easton, Pa. to Bloomsbury, N. J.
HERMANN, K. L.—from 242 Medbury Ave. to 909 Burlingame, Detroit, Mich.
KEIDEL, E. E., (M-1)—from 2313 Searsdale Ave. to 3379 W. 97th St., Cleveland, O.
LAU, F. C.—from 1437 W. Jackson Blvd. Chicago to 242 S. Kenilworth Ave., Oak Park, Ill.
LEE, JOHN, (M-9)—from Box 351 to Box 531, Ingersoll, Ont., Can.
LEITNER, FRED—from 258 Chadwick Ave., Newark, N. J. to Westfield Ave., Scotch Plains, N. J.
LYNCH, A. S.—from 367 Elm St., New Haven, Conn. to Box 94, Whitneyville, Conn.
MANLEY, R. S., (M-12)—from R. F. D. 2, Harrisburg, Pa. to 410 Perry Apts., Davenport, Iowa.
MURPHY, PATRICK, (M-11)—from 625 Gifford St. to 509 Grand Ave., Syracuse, N. Y.
SHERMER, N. H., (M-4)—from 96 St. James St. to McKinnon Industries Ltd., St. Catharines, Ont., Can.
SMITH, R. O.—from 4019 N. Union Ave. St. Louis, Mo. to Care Burroughs Adding Machine Co., Detroit, Mich.
SWANBERG, C. G.—from Gen. Del. to 1746 E. Williams St., Decatur, Ill.
THOMAS, C. H.—from 499 Ridgewood Ave., Glen Ellyn, Ill. to 626 S. Harvey Ave., Oak Park, Ill.
VAN GILDER, C. L.—from 4205 N. St. Louis Ave. to 6123 N. Lincoln Ave., Chicago, Ill.
WATERBURY, FRED, (M-1)—from 28 Mill St., Schenectady, to R. D. No. 2, Delanson, N. Y.
WEEKS, R. T.—from 25 S. Broad St. to Box 80, Johnson City, N. Y.
WORTH, C. B.—from Vulcan Eng. Co., Jackson, Mich. to 501 W. Liberty St., Ann Arbor, Mich.
WYZALEK, J. F.—from 382 S. 21st St., Irvington, N. J. to 160 Chestnut St., Kearney, N. J.
ZIMMERLI, F. P., (M-1)—from 5106 Woodward Ave. to 459 Hancock W. Detroit, Mich.

MAIL RETURNED

BALL, WM. G., Randolph St., Detroit, Mich.
GORHAM, WM. R., 53 Aza Kominato, Kitagate Machi Juniten, Jokoham, Japan.
HANCOCK, GEO., M., Union Charcoal & Chemical Co., Rochester, N. Y.
HOWE, H. A., Standard Heat Treating Co., 1971 Guoin St., Detroit, Mich.
HUNTER, GEO. C., Hotel Huron, Cleveland, O.
LAWRENCE, A. H. M., 511 West Grove, Ontario, Cal.
LEININGER, J. R., 308 West Packer Ave., Bethlehem, Pa.
LIVINGSTON, EDDIE, (M-4), 1208 S. Seventh St., St. Louis, Mo.
JARDINE, J. J., Y. M. C. A., Syracuse, N. Y.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri Cities—First Thursday following first Monday.

Washington—Second Friday.

ROCKFORD CHAPTER

FOLLOWING is a report from the *Rockford Morning Star* of Dec. 13 which quite well presents an account of the initial meeting of the Rockford Chapter at Rockford, Ill., Dec. 12:

"Nearly 100 steel treaters of Rockford gathered last night at the Nelson hotel for the first monthly banquet and business session of the Rockford Chapter of the American Society for Steel Treating. A good dinner and an excellent address were followed by a general discussion of problems confronting local workers in steel.

"William H. Eisenman, Cleveland, O., National Secretary of the organization, delivered a splendid talk on steel treating. His remarks were filled with humorous anecdotes which kept his audience smiling while he drove home the points of his discussion.

"Steel treating, said Mr. Eisenman, began with Adam and Eve, for the race was young when the discovery of steel was made, probably by the building of fires on mineral sands. This, said the speaker, would have led to the discovery of chunks of metal in the ashes, formed by the heat. He recited in detail the various steps in which progress in the use of steel and in the treating of it to obtain varying degrees of hardness was made.

"Ancient writers were quoted by Mr. Eisenman to show that the knowledge of heat treatment existed at the dawn of civilization.

"Superstitions that survived for centuries, becoming 'trade secrets' were gone into in detail. Certain waters were supposed to be more effective in quenching the heated metal and every manufacturer of steel in the early days of the industry had his own special brand of liquid for this purpose—one mixing garlic with brandy, another using the blood of slaves, and others introducing their own odd mixtures. One medieval treatise on heat treatment asserted in connection with the blood method that 'red-headed boys were advocated for the finest grades of steel.'

"Getting down to the present time, the speaker told of numerous modern methods of doing the work, some of which show a great similarity to

those of the ancients. He spoke of visiting many American plants and asserted that the idea of secrecy in methods was rapidly giving place to a desire on the part of steel treaters to exchange ideas for the improvement of the science.

"This spirit of co-operation, declared Mr. Eisenman, forms the basis of the American Society for Steel Treating, a society which, he said, is not a money-making proposition, but purely an educational organization. Every question that puzzles steel treaters is taken up by the society and a solution found. Members present their individual problems, the solution of which the society undertakes. Papers on the various technicalities of steel treating which are read at the monthly meetings of the 32 chapters are published every month in the society's TRANSACTIONS, a 160-page book which is sent free to every member.

"Horace H. Clark, Chicago, acting chairman of the Chicago chapter of the society, was present and in a short address congratulated the local men for the large number present, which, he said, was proportionately much greater than ordinarily enjoyed by new chapters.

"'Instead,' said Mr. Clark, 'of coming out here to tell you men how to organize, I find I am getting pointers that I shall be glad to take back to our Chicago chapter. I want to find out how your committee did in a few weeks what it has taken most of us months to do in the way of getting organized.'

"Of those who sat down to the dinner last night, 31 were members of the local chapter. Before the program was over 26 additional applications for membership were in the hands of the secretary and a number of others were promised. There are about 150 men in Rockford interested in steel treating and thus eligible for membership.

"Otto F. Muehlemeyer, chairman of the Rockford chapter, acted as toastmaster last night and made the address of welcome to the guests. Other officers of the chapter are: Oscar Harrison, vice chairman; R. M. Smith, secretary-treasurer; and Charles Cotta, John B. Frederick, C. R. Crain and A. H. Memiring, directors.

"Charter members of the chapter, all of whom were in attendance at the dinner last night, were C. D. Barrand, R. G. Burmeister, J. J. Burns, Charles Cotta, C. R. Crain, John Dahleen, John B. Frederick, E. M. Greenslit, James F. Gorrell, O. H. Harrison, Will Hickox, George J. Johnson, Edwin Knapp, P. H. Landis, G. W. McKee, A. H. Memiring, A. M. Monks, O. T. Muehlemeyer, George Nash, J. A. Nelson, Otto Olson, J. L. Rossier, R. M. Smith, A. W. Swanson, W. G. Thomas, C. V. White, H. L. Waisner and W. K. Young."

NORTHWEST CHAPTER

The November meeting of the Chapter was held on Nov. 28 at the Manufacturers' Club, Minneapolis. H. K. Briggs, Minneapolis Electric Steel Castings Co., presented a paper on "Instruments and Apparatus, Pyrometry, Microscopy, Physical Testing and Furnaces," which was illustrated by lantern slides.

At the meeting of the Chapter Wednesday evening, Dec. 7, the members had the pleasure of meeting F. P. Gilligan, National President of the Society. Mr. Gilligan is making a tour of the country visiting 32 local chapters of the Society. He was very favorably impressed with the work being done by the local chapter, which is known as the Steel Treaters'

Section of the Manufacturers' Club, and was enthusiastic about the educational course being conducted for the benefit of those who are interested in studying the fundamentals of metallurgy and steel treating. Mr. Gilligan left Thursday, Dec. 8, to visit the St. Louis Chapter.

NEW HAVEN CHAPTER

The New Haven Chapter held a very interesting meeting in the Chamber of Commerce room, New Haven, on Friday evening, Nov. 18. Due to the miserable weather conditions only about 50 were in attendance. The meeting itself was enthusiastic and both papers very interesting. William R. Bennett, president of the Bennett Heat Treating Co., Elmwood, Conn., gave a practical paper entitled, "Atmospheric Conditions in a Heat Treating Furnace and How to Control the Same."

The other paper was given by N. B. Hoffman, chemist and metallurgist, Colonial Steel Co., Pittsburgh, Pa., and was entitled, "Ghost Lines and Grain Elongation in Hot-Rolled and Cold-Drawn Iron Wire and Tool Steel."

One of the best meetings held by the local chapter took place in the assembly room of the New Haven Gas Light Co. on Dec. 21. James Black, foreman of heat treating, Geometric Tool Co., Westville, Conn., presented an interesting paper on "The Importance of Uniformity in Heat Treating." Dr. Paul C. Doerr, metallurgical engineer, Springfield, Mass., spoke on "Principles of Carburizing, Quenching and Tempering." These two papers appealed to both the technical and practical men, and in consequence there was a very large attendance. A lively discussion on both subjects proved of much value as well as the interesting questions taken from the question box. After the meeting a smoker was held followed by refreshments and all of the members enjoyed the good fellowship of the New Haven Chapter.

The next meeting will be held Jan. 25 at Yale University.

PITTSBURGH CHAPTER

Prof. H. F. Moore, University of Illinois, Urbana, Ill., delivered an address on "The Fatigue of Metals," at the meeting of the Pittsburgh Chapter on Dec. 6, at the Hotel Chatham. His address which was illustrated with motion pictures and lantern slides was based on the reports of an investigation into such phenomena conducted by himself and Prof. J. B. Kommers, also of the university, in co-operation with the National Research Council, the Engineering Foundation and the General Electric Co. Professor Moore discussed at length the phenomena of the fatigue of metals and concluded with a review of the progress made by the investigation up to date. The meeting was attended by probably one hundred members and their guests.

A meeting of the Council was held on Dec. 19 to discuss plans for the spring sectional meeting of the National Society in Pittsburgh in May.

LEHIGH VALLEY CHAPTER

Geographically located in one of the greatest industrial centers of the United States and perhaps of the world, the Lehigh Valley Chapter is spurred on to maintain an equal footing among the valleys' technical societies. That they are capable of doing it was most evident when on Nov. 28, 130 members and guests braved one of the worst storms experienced in the valley for a long time to attend a dinner-meeting given

National President F. P. Gilligan, of the Society at Kurtz' restaurant, Bethlehem, Pa.

Dinner was served promptly at 7 o'clock in the banquet room of the famous restaurant. Following the dinner and prior to the introduction of President Gilligan, 15 minutes was devoted to mirth and joviality wherein those present were given an opportunity to become better acquainted. It was at this time that the members were surprised by an orchestra composed of five artists, members of the chapter. With the able assistance of song leader "Bill" Laury the orchestra held the enthusiasm at highest pitch.

President Gilligan, upon being introduced, addressed the meeting on "Quality First." Mr. Gilligan held the closest attention as he forcefully impressed the value and importance of his subject. The talk was illustrated with slides. Many photographs as well as photomicrographs were shown of failures which occurred in tools and machine parts due to faulty material, improper design, and carelessness or the short circuiting of the heat treating. Throughout his entire talk Mr. Gilligan laid great stress upon the present day tendency to place production and not quality first.

Among the guests present were T. D. Lynch, research engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; W. Williams, metallurgist, Billings & Spencer Co., Hartford, Conn.; and W. O. Hearsey, division superintendent, Bethlehem Steel Co., and president Lehigh Valley Engineers' club. Each in turn spoke very highly of the opportunities which the society offered to those using steel or steel products.

There was no December meeting of the chapter. The committee announces that the next meeting will be the third of the series on "The Manufacture, Treating and Testing of Steel," and will be held in the Public Library auditorium, Easton, Pa., Jan. 9, 1922. This meeting will be addressed by Messrs. W. Cutter and W. G. Walton, of The Bethlehem Steel Co., on "Rolling Mill and Foundry Practice".

PROVIDENCE CHAPTER

W. C. Peterson, metallurgist of the Atlas Crucible Steel Co., spoke before the Rhode Island chapter at Providence on Wednesday, Nov. 30. This proved to be an excellent meeting due to the fact that Mr. Peterson handled his subject "Tool Steel and Its Heat Treatment" in such an acceptable manner. The subject dealt particularly with treatment of dies, reamers, broaches, files; also preheating and its different phases, machining tool steels, and the value of fillets.

NEW YORK CHAPTER

A very enthusiastic and well attended meeting of the New York Chapter was held in the Engineering Societies building, Wednesday, Nov. 16. Over one hundred members and guests were present, and they enjoyed a very interesting address by T. Holland Nelson, works manager of the H. Disston & Sons, Philadelphia, Pa., who gave an illustrated talk on crucible steel making as practiced in England and in America. Mr. Nelson spoke with the authority which comes from many years of experience, both in his native town of Sheffield and in various American works.

Previous to the paper of the meeting, E. E. Thum, associate editor *Chemical & Metallurgical Engineering*, New York, in reviewing current events of interest to metallurgists, called attention to recent publications on the investigation of metallic structure by X-rays, and a modern adapta-

tion of forge practice called "hammer welding", used for making large welded boilers, pressure containers, and pipe.

The program committee feels very much gratified in the response of the local membership thus far this year, and takes it as an indication that their plans for the year are along the right lines. These consist of a series of evenings, each of which will cover some phase of the heat treaters' work, and be handled by an expert in that particular line. Next month the chapter will entertain National President Gilligan, who will speak on the subject "What Happens to a Piece of Steel When You Heat and Quench It?"

The practical talks for 1922 are as follows:

JANUARY:—Annealing and tempering machine and tool steels.
FEBRUARY:—Case hardening (carburizing and subsequent heat treatment). Ways of doing it, and what it does to a piece of steel.
MARCH:—Treatment of high speed steel.
APRIL:—Hardening room troubles, shrinkage, warpage and scaling.
MAY:—Up-to-date hardening room equipment, furnaces, pyrometers and auxiliaries.
JUNE:—Spotting the reason for failures in service. Practical uses for microscopes and physical testing machines.
Added Attraction:—Current events, a 10-minute talk at each meeting on recently published items of interest to heat treaters. Come to the meetings and get into the discussions of the topic presented.

CLEVELAND CHAPTER

The November meeting of the chapter was held at the Engineering Society's room, Hotel Winton, Friday evening, Nov. 25, and consisted of discussion of questions submitted at the previous meeting. Each question was assigned to a member to open the discussion. The questions submitted were as follows: "Heat Treatment of 3-Inch Forgings to Obtain Certain Physical Properties", by Ray T. Bayless; "Ageing and Heat Treatment of Cast Iron", by Robert Archer; "Effect of Silicon in Tool Steel", by J. V. Emmons; "Effect of Pickling" and "Carburizing High Speed Steel", by W. S. Bidle. About 65 members were in attendance at the dinner and over 30 members participated in the interesting discussions.

The December meeting was held at the same place on Dec. 9 and was addressed by Prof. H. F. Moore, of the University of Illinois. Prof. Moore's talk on the "Fatigue of Metals" was illustrated by slides and moving pictures, and proved to be one of the best meetings from the point of attendance, 200 being present, that the chapter has held this year.

SYRACUSE CHAPTER

The chapter had a well attended meeting in the Yates hotel on Friday, Dec. 2. D. D. Ormsby, chief engineer, Brown Lipe-Chapin Co., Syracuse, N. Y., read a paper, "Automobile Rear Axle Gears". After a terse description of the various systems of gears he dwelt on the problems that confront the designer of gears for automobiles, describing carefully the necessity of meeting conditions induced by automotive design. He mentioned in passing the various type of materials used, the machines to produce the gears and finally the troubles caused by the hardening process. The audience, made up largely of men from various other gear plants of the city, questioned Mr. Ormsby closely on best practices and safeguards to insure a good product.

Mr. Howell's paper, "The Designing of Tools," was well received since he addressed an audience that had experienced difficulties in hard-

ening tools of poor design. His paper covered tools, jigs and fixtures usually found in a gear plant. Especial interest was shown by the steel men present in the matter of broaching. This is a problem that bothers, and is a hard operation to perform on account of the size and shape of holes to be broached and the condition of the material.

HARTFORD CHAPTER

The regular December meeting of the Hartford Chapter was held on Dec. 8 at the assembly hall of the Hartford Y. M. C. A. The audience numbered 125, of whom 35 were members and 90 were nonmembers. The meeting started with musical entertainment provided by Mr. Hathaway's entertainment committee. Then Mr. Rockwell introduced new members and guests to the meeting. Mr. Graham, of the New York Chapter, announced the plan for sectional meetings during the winter, with particular reference to the New York meeting in March, and called for volunteers to present papers at that meeting.

George P. Moore, metallurgist of the Wallace Barnes Co., Bristol, Conn., read a paper dealing with design, materials, heat treatment, and inspection of springs, as carried out in that plant. He also exhibited numerous samples of springs of various types, and failures to which these springs were subject. Owing to an accident occurring to the car in which he drove to the meeting, it was necessary to abandon the greater part of the samples on the road, the party being forced to transfer to another already crowded car. His paper was very interesting and valuable, in that it covered the entire manufacture from the design to the finished product. The paper will be available for publication, and the chapter believes that it would be a valuable addition to the TRANSACTIONS. Many of the audience announced their desire to acquire a copy of the paper, and it is probable that a limited number of type-written copies will be made for distribution within the chapter. After Mr. Moore's paper was read, open discussion took place, and many questions relating to specific uses were discussed.

The final feature of the meeting was a description of a somewhat common effect observed in the heat treatment of high speed steel. After hardening, the high speed tools exhibited by Mr. d'Arcambal, showed a file-hard surface. When the tool was fractured, however, the fractured surface could be filed easily. Examination of the tool, which was not over 0.25 inch thick, showed that it possessed a thin hardened skin, having a thickness of only 0.002 or 0.003 inch, the remaining interior portion being quite soft to the file. Tools of this sort appeared to be properly hardened when tested with the file, but after the first grinding in service, were found to be useless. In the discussion that followed many opinions were offered as to the reason for this effect. It developed that this effect had been noticed only in the 18 per cent tungsten type of high speed steels, and then only when the carbon content was in the range of 0.50 to 0.60 per cent. The effect is undoubtedly due to the relatively low carbon content. Failures of this sort can be guarded against only by careful inspection and chemical analysis of the bar stock before shaping into tools.

Mr. d'Arcambal also told of experiments he had made to determine the effect of furnace temperature on the rate of heating of a cold tool placed in the furnace. He gave as examples the following: Two pieces of steel of the same shape and size were placed at the same time in two

similar furnaces, one of which was running at 1400 degrees Fahr. and the other at 1800 degrees Fahr. It would seem natural for the piece placed in the 1400 degree furnace to reach the furnace temperature first, but as a matter of fact, the 1800 degree piece was first. The difference in temperature gradient, also the proximity of the 1400 degree heat to the critical point of the steel play a part in this paradox. Similar tests have been described recently in the metallurgical press, in which the same results were obtained.

The subject of the January meeting was announced at the close of the meeting. H. J. French, of the Bureau of Standards, Washington, will speak on the work and equipment of the bureau. His talk will be illustrated by lantern slides and possibly by moving pictures. He should be able to interest all by a description of some of the problems investigated and solved by the bureau.

Unless otherwise announced in the monthly poster notices, the regular monthly meetings of the chapter will be held on the Thursday nearest the 10th of each month, at 7:45 p. m., in Jewell Hall, Y. M. C. A., Hartford.

The date and program for each meeting is as follows:

JANUARY 5:—"The Relation of the Bureau of Standards to Industry," by H. J. French, Bureau of Standards, Washington.

FEBRUARY 9:—"High Speed Steel," by A. H. d'Arcambal, Pratt & Whitney Co., Hartford, Conn.

MARCH 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.

APRIL 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Mathews, President Crucible Steel Co., Pittsburgh.

APRIL 29:—9:00 a. m., Inspection of New Departure Co. Plant, Bristol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.

MAY 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.

JUNE 8:—Annual Banquet. Speakers to be announced later.

In addition to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

WASHINGTON CHAPTER

On Friday Dec. 16, the Washington Chapter was addressed by N. B. Hoffman, of the Colonial Steel Co., his subject being "The Hot Rolling and Cold Drawing of Low Carbon Steel Wire." Inasmuch as rods and wire find many applications in general construction as well as special application in ordnance, aircraft and naval construction, the paper proved of special interest to the chapter. The speaker has had extensive experience in the manufacture of these products. The effect of composition, rolling or drawing, heat treatment; the causes of flaws in wire products and the relation between these flaws and the condition of the material were discussed by Mr. Hoffman.

INDIANAPOLIS CHAPTER

The Indianapolis Chapter had a very interesting paper presented on Nov. 21 by H. G. Hall, a representative of the Bristol Co., on the subject of "Cold End Compensation in Pyrometry". Mr. Hall's paper was illustrated with lantern slides and moving pictures.

The annual visit of President Gilligan occurred on Monday night, Dec. 5 when 75 members were present to attend a smoker in honor of

the President. Mr. Gilligan spoke on activities of the Society, and also presented stereopticon slides illustrating his talk, "Quality of Material and Workmanship". The meeting was considered to be one of the best ever held by the Indianapolis Chapter.

CHARLESTON CHAPTER

The Charleston Chapter had an excellent meeting at the Kanawah Hotel on Tuesday evening, Nov. 22, when the National Secretary, W. H. Eisenman was present and spoke to the members with reference to the activities of the Society. J. E. Arthur presented a paper the same evening on "Steel Melt Shop Practice". Mr. Arthur's paper produced good discussion.

The Charleston Chapter is in an excellent condition due to the active interest and co-operation of all its members. Chairman Priestley is taking a special interest in providing good speakers for the coming meetings. On Dec. 13, H. J. French, Bureau of Standards, presented an interesting paper on the work at the Bureau, while W. H. White of the local chapter presented a paper on "Sand Casting and Iron Mold Practice."

The chapter has adopted the practice of having a short paper presented by some member of the local chapter on the same evening that it has an out-of-town speaker. President Gilligan will pay his annual visit to the Charleston Chapter on Jan. 19 when the subject of "Forging Practice" will be presented by C. A. Gosztonyi. The local speakers and the dates of meetings for the coming meetings are as follows:

FEBRUARY 7:—"Heat Treatment of Carbon and Nickel Forgings and Castings," by A. F. Mitchell.
MARCH 7:—"Heat Treatment of Chrome-Nickel and Molybdenum Steels," by H. W. Fullmore.
APRIL 4:—"The Necessity of High Quality Steel for Ordnance Purposes," by C. E. Margerum.
MAY 2:—"The Chemical Laboratory and Its Relation to Shop Operations," by Harry Schagrin.
Election of New Officers.
JUNE 6:—"The Inspection of Ordnance Forgings," by J. E. Holden.

Chairman W. J. Priestley was unable to attend the first fall meeting of the Chapter but sent a communication to the members of the Chapter which was read by the secretary. His remarks were of interest and for the benefit of the Society are reproduced as follows:

September 28, 1921.

Fellow Members:—

I am exceedingly sorry not to attend tonight's meeting. I assure you that my absence is in no way indicative of my interest and enthusiasm in the welfare of the Society.

I wanted to tell you tonight what the Society stood for and what it means individually to you men who make your living in the steel industry. There has been an awakening in the entire steel industry since the war. I believe in the future, all steel makers are going to pay more attention to quality of product instead of tonnage. The automobile manufacturers have had this vividly impressed upon their product and nearly all such factories today have well equipped heat treating establishments and research laboratories where they are endeavoring to improve their product all the time.

Those of you who have been in the steel business for eight or ten years will agree with me that many steps forward have been taken in the last five years. I have in mind a steel foundry in one of the largest plants in the country which five years ago did not even have pyrometers on their furnaces for annealing castings. These furnaces were coal-fired, open-top types, and when it was suggested to the superintendent of the foundry that he had better get in a requisition for some electrical pyrometers on his furnace, he threw up his hands in horror and

became very indignant. This same man had lying out in his stock yard at that time, castings which had been made fourteen months previously, which he had been unable to pass merely on account of improper annealing. Subsequently, all these castings were annealed and at least 90 per cent of them passed test. This is only one illustration of the many instances that might be cited how people in the steel industry were groping along in the dark several years ago.

I know another instance of a government establishment which six years ago, was ordering heat treated blooms and billets, and pulling tests on the same for acceptance in spite of the fact that these blooms and billets were subsequently forged and given an annealing without any heat treatment or testing after forging. I think that a state of affairs like the two instances cited above are due to the fact that men in the shops have not been able to broaden and know what other people are doing. If there is no other benefit which men in the steel business can get from the American Society for Steel Treating, they can at least get ideas from other people who come here to talk; from discussing subjects at the meetings, and developing and drawing out their own ideas.

I also want to present to you the idea that the American Society for Steel Treating is for men in the shop as well as for technical men. The heat treatment of steel takes in such a large field, there is so much detail to it, that the co-operation and support of both the practical men in the shop, metallurgists, and heat treatment men, or supervisors, should all be combined in order to get the best results.

I also want to state that the Society is not limited to men who are employed in the heat treatment of steel alone. Melters, forgers, machinists, and all other men who make their livelihood in any branch of the steel industry are eligible to membership in this Society. Every one who is in the steel business owes a certain amount of his time to the development and upbuilding of the art or science of making steel. Everybody has an opportunity to contribute papers to the Society and I want to encourage all the members to pick out a subject and prepare a paper to be read some time. You will be surprised to find out how much benefit you will receive from the preparation of a paper. You men who think you know your own subject perfectly well, and probably do for the routine work you have to do, find when you come to put down certain facts which you know are likely to be discussed or criticized by others that you are going to go deeper into the subject than you would otherwise.

A successful steel plant which has such a variety of departments, must have each and every department functioning smoothly and without friction. The American Society for Steel Treating affords the machine shop men some insight into the problems that the steel melter, forger and heat treatment man are up against, and when he finds a defect in a forging or casting, he is not going to be so inclined to criticize and blame the other man for not being on the job, but is going to have a better understanding of the work himself and probably from an entirely different point of view, and thus he may be able to make suggestions to the heat treatment or melt shop men. The same applies to the man that forges steel made in another department than his own. I have seen in many steel plants too much "buck passing." I think this comes not so much from a malicious spirit or "I don't care" spirit as it does from the fact that men in the various departments do not know enough about the other man's problems. This Society affords men a broader vision and a better outlook in their entire work.

The American Society for Steel Treating affords men an opportunity to advance and improve their education. No man wants to stand still. Every one of you has an ambition to go ahead. When you belong to this Society, you receive papers prepared by men at other chapters. By careful reading of the papers, attending meetings of your own chapter and entering into discussions, you will soon find your vision broadening and you will get yourself in line for positions of greater responsibility.

I wish also to impress upon you that as a member of the Society, you belong to one of the strongest, most aggressive and rapidly growing societies of the country today. The Society now is about two years old and has a total membership of 3200 men. This membership is made up of the most prominent steel men in the country who are leaders in other major metallurgical and technical societies The National Society is directing its efforts along well defined and practical lines. I understand it was decided at the National Convention recently held in Indianapolis, to establish a research committee which would carry on in certain laboratories practicable lines of research which have never heretofore been undertaken.

At this first meeting of this season, I desire to have you hear what your three

representatives learned at the Indianapolis convention. Your committee on meetings and papers have made arrangements for a prominent out-of-town speaker for the next meeting.

We now have about 50 members in the Charleston Chapter. We have a great deal of talent in this Chapter already—but there are many more men in this community whom, I feel would make valuable additions to our Society and I hope that they will take kindly to our invitations and come with us. I want every present member of the Society to consider himself a member of the Membership Committee, and bring his friends around to some of the succeeding meetings. I want to impress upon you that Charleston Chapter will be a great success, only, as you men make it. I also wish to impress upon you that all you get out of it will depend upon the interest and the work you do in the Society. Don't feel that because you are not a literary genius that you cannot write a good paper. We want you to come to all the meetings regularly and enter into the discussions which take place after the reading of papers.

BOSTON CHAPTER

Through the courtesy of the Massachusetts Institute of Technology, the Boston Chapter held its initial laboratory meeting at the institute on the evening of Dec. 9. A large number attended. Irving H. Cowdrey, chairman, presided and introduced Harrison W. Hayward, professor of materials of engineering at the institute. For the benefit of those not familiar with a testing materials laboratory, Professor Hayward explained first its functions—routine, research, testing of structural steel, and just what constituted each kind of work under these headings. This was followed by an explanation of the relation of the laboratory to industry, a lesson in the proper use of terms used in connection with laboratory work, and finally, useful information regarding the preparation of specimens to be presented for laboratory testing.

Following Professor Hayward's remarks, the members visited various laboratory divisions of the institute, and with the aid of laboratory result sheets, witnessed tests made on a large number of specimens furnished by various steel companies. For the institute, A. C. Fales and I. N. Zavarine conducted tests in the heat treating laboratory; Victor Homerberg in the metallographic laboratory; R. G. Adams in the autographic testing, hardness and shock testing laboratory; and C. A. Chayne and E. M. Brickett in the commercial testing laboratory. In the shock tests, Mr. Adams was assisted by Mr. Cowdrey. An open discussion followed the testing, many questions being asked and answered by Mr. Cowdrey, and those in charge of the testing machines. Members attending agreed the meeting was the most interesting held by the Boston chapter and an effort will be made to hold another meeting at the institute.

CHICAGO CHAPTER

At its November meeting held at the City Club, the Chicago Chapter had a question box in which a large number of members took a very active part. There was much interest displayed throughout the evening and little hesitancy in asking and answering questions.

The December meeting was held at the City Club on Thursday evening, Dec. 8. The speaker was Dr. Zay Jeffries, of Cleveland. Dr. Jeffries' paper on the "New Theory of Hardening" was illustrated by lantern slides and proved one of the most interesting papers presented before the local chapter. This was due to several reasons among which are: Dr. Jeffries' complete mastery of the subject, his pleasing and entertaining presentation of the subject matter, as well as many apt illustrations Dr. Jeffries gave in order to assist those present in visual-

izing the points under consideration. The discussion following the presentation of the paper was productive of further interest in his paper.

ST. LOUIS CHAPTER

The December meeting of the St. Louis Chapter was held at the American Annex Hotel on Dec. 9. President F. P. Gilligan spoke on "Quality of Material and Workmanship", and by the able presentation of his paper provided a very valuable evening for those in attendance. President Gilligan's paper was well received. The meeting was very successful from the time the dinner started at 7 p. m. to the close of the executive meeting at 11 o'clock.

SOUTH BEND CHAPTER

The South Bend Chapter held its meeting on Dec. 13 at 8 p. m., in the Studebaker Recreation building. Several short discussions were given covering different subjects, and these were followed by general discussion of the subjects presented. Refreshments were served.

ROCHESTER CHAPTER

The Rochester Chapter held its meeting on Wednesday, Dec. 14, at 8 p. m. in the Rochester Engineering Society club rooms. The chairman of the Chapter, L. K. Marshall, presented a paper entitled "Tool Steel Manipulation". The United States Bureau of Mines loaned the chapter two highly interesting and instructive films on "The Story of Abrasives" and "The Story of Rock Drilling".

DETROIT CHAPTER

The Detroit Chapter held its meeting on Nov. 25 at the Board of Commerce at 8 o'clock. James Schemerhorn presented a paper on "The Hearth and the Home". There were about 100 in attendance. A membership drive was inaugurated at this meeting.

The December meeting of the Chapter was held on Dec. 15 at the Board of Commerce. J. M. Watson, metallurgist, Hupp Motor Car Corp., spoke on "The Relation of the Metallurgical to Other Departments".

SPRINGFIELD CHAPTER

About 50 members visited the Rolls Royce plant on Dec. 3. This excursion proved to be a most interesting trip, and the courtesy of the company in opening its plant for inspection as well as the cordial reception of the visitors was thoroughly appreciated.

The Chapter held its meeting on Dec. 16 at the Chamber of Commerce. The speaker of the evening was V. E. Hillman, metallurgist, Crompton & Knowles Loom Works, his subject being "The Efficiency of Different Mixtures for Cyanide Hardening". Mr. Hillman's paper was illustrated with lantern slides.

TRI CITY CHAPTER

The Tri City Chapter had a very pleasant meeting on Friday, Dec. 9, when J. Fletcher Harper, research engineer, Allis-Chalmers Co., presented an interesting illustrated paper on the "Effects of Deep Etching". Mr. Harper's paper was thoroughly enjoyed by the large number present and an

interesting discussion followed. The National Secretary, W. H. Eisenman was also present and spoke to the members on "The Activities and Progress of the Society".

As an added attraction moving pictures of the Commonwealth Steel Co. were shown and produced a large amount of favorable comment. An excellent dinner at the Davenport Chamber of Commerce preceded the meeting. The local chapter is having a very successful winter; the meetings are well attended and have been uniformly successful. This success is due to a large measure to the co-operation the officers and executive committee received from the entire membership.

As a means of impressing upon members the dates of meetings, the Tri City Chapter sends to members desk blotters on the righthand end of which is a calendar for the month with the date of the meeting printed in red ink. The lefthand end of the blotter shows the date of meeting, place, speakers, subjects and chapter officers.

MILWAUKEE CHAPTER

The Milwaukee Chapter held its regular meeting at the Medford Hotel on Tuesday evening, Dec. 13. The National Secretary, W. H. Eisenman, paid a visit to the chapter and discussed with them the activities of the National Office during the past and the coming year. Moving pictures of the Commonwealth Steel Co. were shown, and proved very interesting to those in attendance.

CINCINNATI CHAPTER

The Cincinnati Chapter's November meeting was held on Nov. 25 in the Odd Fellows Temple. W. R. Fleming, of the Andrews Steel Co., presented an interesting paper on "The Influence of Nickel and Chromium in Steel" and was followed by a general discussion.

S. J. Felton, metallurgist, Lunkenheimer Co., presented a most interesting paper on "The Hardness of Steels and Cast Iron", on Friday, Dec. 16 at the Ohio Mechanics Institute.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held its November meeting on Nov. 25, at 8:15 in the Engineers' club. The speaker of the evening was Arthur W. F. Green, John Illingworth Steel Co., his subject being "Preparing Tool Steel at the Mill."

WORCESTER CHAPTER

The Worcester Chapter has issued another of its mimeographed reports of discussions held at the meetings. This discussion was on Dr. Hoffman's paper and consisted of 12 pages. The sending of these mimeographed reports of discussions to members is meeting with pronounced favor.

The November meeting was addressed by W. C. Peterson metallurgical engineer of the Atlas Crucible Steel Co. Mr. Peterson covered the following points: Heat treatment of dies, reamers, broaches, dies, files, punches, saws, milling cutters, die blocks and chisels; various types of steel used;; hardening and drawing temperatures; breakage; causes of failure; importance of fillets; preheating; rate of heating; difference between water and oil hardening steels; steels for hot work; alloy steels; and machining strains. Because of Mr. Peterson's wide experience as supervisor of materials in the laboratory at the Packard Motor Car Co. for 12 years, he was able to speak from actual experience and an intimate knowledge of shop practice.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, February, 1922 No. 5

PAPERS FOR NEW YORK MEETING ARE PREPRINTED

ON FRIDAY, March 3, the Society will hold its first sectional meeting in New York. Special effort has been made to make this meeting a success, the New York Chapter having rendered much assistance in the arrangement of the final details. Hotel McAlpin, Broadway and Thirty-fourth street, will be the headquarters for both registration and meetings. It is urged that members expecting to attend the meeting make hotel reservations without delay. Within the next few days all members of the Society will be advised by mail as to the complete program for the meeting.

As far as the technical sessions are concerned, some six papers will be presented. Five of these papers are preprinted and appear on pages 369 to 395 of this issue of TRANSACTIONS. This is the first time that papers to be presented at the Society's meetings have been printed in advance, although the advantage of so doing has been recognized. It now will be possible for members to become familiar with the papers before they are presented by the author, thus the discussion which is provoked should prove of great value. It is to be hoped that more discussion will be forthcoming and that a greater number will enter into it. As a matter of fact, greater benefit frequently is derived from discussion of a paper than from the paper itself. The New York meeting has every indication of producing gratifying results.

ANNUAL CONVENTION DATE IS CHANGED

THE 1922 Convention and Exhibtion of the American Society for Steel Treating was originally announced for the week of Sept. 25 to 30 at Detroit, but it has become necessary to postpone the date another week so that the convention will be held during the first week of the following month from Oct. 2 to 7.

Definite arrangements have been made whereby the Society will have the use of the exhibition hall in the General Motors Office building, shown in the accompanying illustration. This exposition hall will give the Society one of the best locations it has ever had. The room is 60 x 500 feet and is well supplied with electrical and gas connections.

The meetings for presentation of papers will be held in the same building as well as the entertainment features and the very best of accommodations will be available.

The Detroit Chapter has appointed its Convention committee of which "Billy" Woodside of the Studebaker Corp. is general chairman, and it is

planned to maintain the reputation established by the local chapters of the cities in which previous conventions have been held.

Floor plans and contracts for space will be prepared and sent out within the next few weeks.

THE RIGHT MAN FOR THE RIGHT JOB

RESULTS that have been obtained by the employment bureau of the Federated American Engineering Societies of New York City in securing positions for unemployed engineers during this industrial depression must be most gratifying to those directly interested and intimately associated with this activity. The plan of operations consisted, briefly, in a committee of unemployed engineers, making a systematic canvass of employers and consulting engineers. The positions, which were discovered in this manner, if not desired by the canvasser, were turned in to the employment office, to be filled from the list of applicants whose names were on file. The greatest benefit probably has been derived not from the mere number of positions filled, but by bringing the employer's attention to the service that this employment bureau is capable of rendering them in filling engineering positions of all grades. The result of this campaign has been at least two-fold; that

General Motors Building, Detroit, Where 1922 Annual Convention and Exhibition Will Be Held

of obtaining positions for some who were out of employment and that of establishing a more tangible connection with employers.

The Employment Service Bureau of the American Society for Steel Treating is a service bureau for the use of all members of the Society. It has the welfare of its members at heart. It has functioned well in the past and must function very much better in the future to be of maximum service to all. The only way in which it can function better than it has is by greater support and co-operation of both employer and employe in making use of services it can render. There are probably more men out of positions at this time than ever before and it is the work of the Service Bureau to bring the men and the positions together.

The ways and means of accomplishing this purpose necessarily will be different from those used by the New York societies due to the fact that our membership is more scattered and cannot be as easily canvassed by personal calls. Our TRANSACTIONS reach approximately 3500 individual members each month and through the columns which are devoted to the Service Bureau, both employer and employe are reached. The results obtained through the activity of this bureau are indeed very gratifying, but it is felt that the full benefit of this service is not being used by enough of our members. In spite of the fact that there has been a marked falling off in business, there has likewise been a large turnover of personnel in many organizations. Although there are many men out of employment these days, many of whom are capable men who have been unfortunate in being members of organizations which have been disbanded, the employer is still confronted with much the same problem he has always been confronted with when he is in need of a new man to fill a vacancy or new position; that of finding the right man at the time when he wants him.

It is our earnest desire that our employment service bureau be an outstanding feature of the Society's activities and it is urged that a much more extended use be made of this department. It is regretted that the postal regulations demand that a small minimum fee be charged for all advertising insertions which are made but these advertisements are not at all a part of the requirements in making use of this service. An applicant does not need to run an advertisement to get the full benefit of this service. All that he needs to do is to communicate with the Society's main office and state his desires and they will be given full and prompt attention. The employer especially is urged to make known his needs so that the Society can aid both him and applicants for positions.

Our motto—*"ALL FOR EACH AND EACH FOR ALL"*—is just as truly our motto today as it was the day it was selected. Can we not all play our full part in making this motto something more than a motto and really be of service to our fellow workers?

RESEARCH VERSUS INVESTIGATION

RESEARCH; a systematic study of certain phenomena by the experimental method.

Investigation; the act of inquiring into systematically.

These two terms are used almost synonymously in referring to any piece of study which may or may not be dealing with facts already established by previous study. There appears to be a decided distinction between investigation and research. An investigation may be a simple inquiry into the causes for a certain result which has been observed. Such an

inquiry may cover perfectly well known facts which were evidently temporarily obscured by other outstanding features of the case. A research as we wish to look upon the meaning of the word is a more profound systematic study of phenomena, the causes for which we are not fully aware.

For several years the Board of Directors has given considerable thought to a proposed research laboratory to be maintained by the Society and to be governed by the Research Committee, under whose supervision would come the problems for study. The cost of such an undertaking would have to be defrayed by the Society or by special subscriptions or endowments.

It is well known that the costs involved in establishing a fully equipped research laboratory such as would be required to study metallurgical problems, would involve upward of $100,000 initial investment. To equip a small chemical and physical laboratory, such as one frequently finds in industrial establishments for routine testing and checking of raw materials, and expenditure of $20,000 to $25,000 usually is involved. Such a laboratory, while suitable for the purpose intended and for certain simple investigations, would be entirely unsuited for conducting real research studies.

If our Society undertakes to proceed with problems of research, it must not be handicapped or hampered with insufficient or improper equipment with which to carry out such work.

The Society feels highly complimented and honored in having been tendered several very cordial invitations to make free use of the facilities and council offered by several nationally known and recognized institutions, which are especially and fully equipped to conduct metallurgical researches. Undoubtedly the Board of Directors will consider the acceptance of one or more of these invitations.

Such a research department, of course, would be for the use and benefit of the members of the Society and the problems for study will, in many cases come from suggestions from the membership at large. The problems which will undoubtedly be selected, will be problems which are vital to certain lines of endeavor and which are knotty and troublesome factors entering into the production of certain structural parts, tools, dies, etc. It would not be the purpose of this research section to investigate the cause of failure of parts or tools, etc., of any individual manufacturer, which failures are only intermittent and probably due to any one of a dozen causes, most of which are traceable to carelessness on the part of some workman. Such problems are for routine laboratories and not for research studies, unless they are chronic difficulties experienced by many manufacturers in the same line of work. The distinction which we wish to bring out, is that the Society does not intend to conduct a department which in any way will interfere with the activities of commercial testing laboratories or consulting engineers, but it does aim to aid in the advancement of the metallurgical realm and especially that of the heat treatment of metals.

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MEMBERS of the Society who may wish to have their TRANSACTIONS bound are directed to page 8 in the advertising section of this issue where complete information with reference to the same will be found.

There has been a heavy demand for the March issue, Volume 1, No. 6 1921 of the TRANSACTIONS, and any member having a copy he wishes to dispose of should forward the same to the National Office where they will be paid for at the rate of 75c each.

COLD HEADED BOLTS—THEIR METALLOGRAPHY AND HEAT TREATMENT

By V. E. Hillman

METALLURGICAL features involved in the fabrication of cold headed bolts will be dealt with in this paper. The history of the art reverts back to the early Egyptians who used hand formed rivets in the construction of their various types of implements. The first commercial development of the process took place in England in 1760, when two brothers John and William Wyatt constructed a machine for heading wood screws. Thirty-four years later, a "cold header" was developed and patented in America. The cold heading industry has made rapid strides during the past decade and today, enormous quantities of bolts ½-inch and smaller are being made by this process. These remarks apply particularly to stove and tap bolts, machine screws, cultivator bolts, wood screws, and sink bolts. Metallurgists contributed their share of thoughtful attention to the advancement of the art by developing a steel that would sustain the duty imposed upon it.

The term, "cold work", implies that energy is expended on the metal when its temperature is below the critical range. The microstructure of the metal prior to the application of cold work consists of an aggregate of crystalline grains or cells, each grain being a structural unit. It may suffer rupture or deformation; it may be enlarged, elongated, stressed, or restored to its normal size and shape. When the metal is subjected to mechanical pressure, the crystals are crushed and intimately mixed. Cold work has an embrittling effect upon the metal and the grains which were originally equiaxed are elongated, assuming a ropy appearance resembling fiber. In brief the grains lose their original identity.

This change in microstructure alters the physical properties of the

A paper to be presented at the New York Sectional Meeting, March 3. The author, V. E. Hillman, is metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

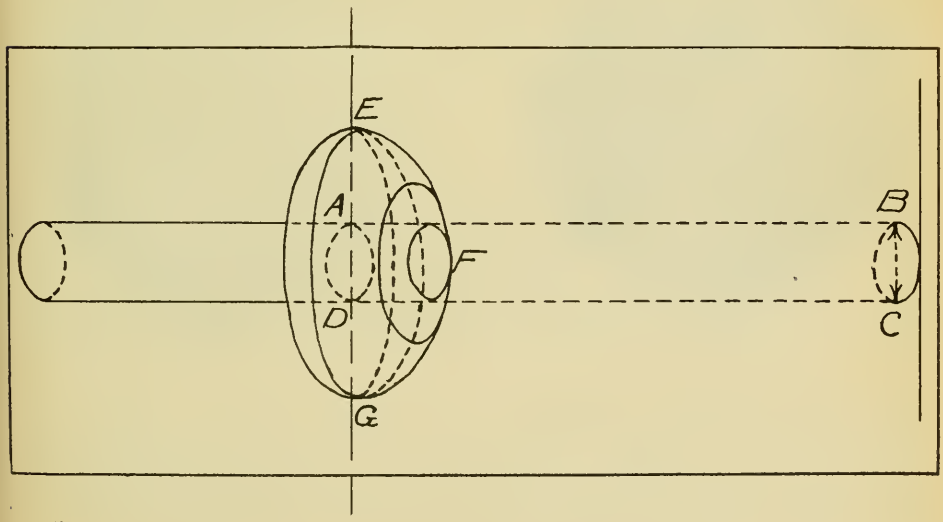


Fig. 1—Sketch showing the maximum amount of stock which may be upset into the head of a bolt without danger from "cold shuts"

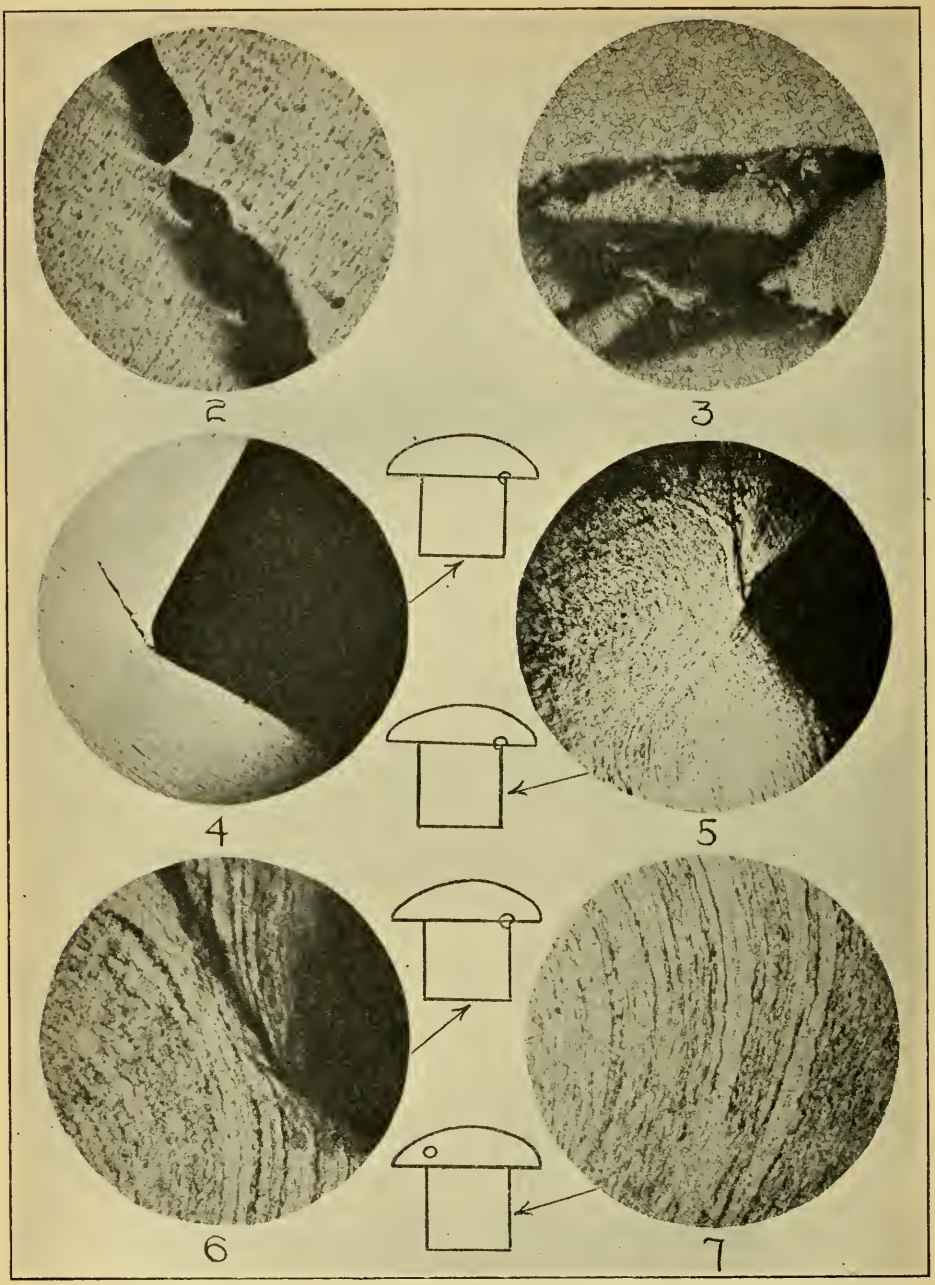


Fig. 2—Unetched specimen of a "cold shut," caused by upsetting too much stock. Note the flow of metal at one point and the isthmus. Etched and X 100. Fig. 3—Another example of a "cold shut." Etched and X 100. Observe strained condition of the metal in the center at extreme left and right. Imperfect flow of metal pronounced. Fig. 4—Manner in which a crack may develop at junction of head and shank, the sharp angle acting as a seat of rupture. Etched and X 45. Fig. 5—Highly strained appearance of grains in vicinity of rupture. Note elongated ferrite band resembling a French curve. Etched and X 45. Fig. 6—Photomicrograph showing banded structure of strained ferrite grains. Etched and X 100. Observe that lines of deformation assume different direction on either side of cavity and that severely strained areas gradually increase as crevice is approached. Fig. 7—Elongation of ferrite and pearlite grains, showing the flattened crystals incident to forming the head. Etched and X 100

steel. The elastic limit, tensile strength, specific gravity, and hardness are increased; whereas, the percentage elongation and reduction of area are diminished. There is a limit to the amount of cold work which a piece of steel will sustain. Therefore, the cold working of the metal must be interrupted from time to time to relieve the internal stresses which have been developed. In other words, if the strained steel be heated to above its critical range, for 15 minutes at 1650 degrees Fahr. and quenched, the elongated grain fibers will be effaced and renewed toughness will be conferred on the metal. The restoration of the ferrite and pearlite grains will permit the application of additional cold work thus cold headed bolt manufacturers usually resort to this thermal treatment.

A lower annealing temperature, 1150 degrees Fahr. for one hour, will also suffice to remove partially at least the embrittling effect of cold work. It should be borne in mind, however, that only the strained ferrite grains are influenced by the lower annealing temperature. The pearlite particles remain in their distorted state. Annealing below the critical range has a dual advantage, namely; the operation is less expensive and the scale nuisance is abated. A comparison of the two heat treatments indicates that the higher annealing temperature produces maximum softness, although the difference in the Brinell values is not appreciable. Certain low annealing temperatures will cause crystallization if the grains have not been sufficiently strained. When the metal has suffered only a slight amount of distortion, an annealing temperature between 1280 and 1380 degrees Fahr. should be avoided, lest a coarse structure may result. In rivets, for instance, where merely a small volume of stock has been upset, it is mandatory to anneal below 1280 or above 1380 degrees Fahr. The above law does not apply to grains that have been subjected to an inordinate amount of cold work, because the distortion is sufficient to render the danger range, 1280-1380 degrees Fahr., inoperative. Light cold work, however, with an anneal between 1280 and 1380 degrees Fahr., will produce a fiery, coarse, crystalline structure. Consequently, crystallization is produced by annealing a critically strained bolt within a certain temperature range. The foregoing remarks apply particularly to steel of the following analysis: Carbon 0.10 0.20, manganese 0.30-0.40, sulphur 0.05, and phosphorus 0.025 per cent.

Soft basic steel is well adapted for cold heading process. The carbon content in the metal, however, should be regulated carefully. It is a well recognized fact that if an attempt be made to upset a piece of high carbon stock, the steel will simply bend over; whereas, material of the proper analysis, 0.10-0.20 per cent carbon, will flow readily into a compact mass. It is necessary to regulate the phosphorus content in steel which is to be subjected to the cold heating operation. The use of basic stock, however, implies that the percentage of phosphorus of necessity will be negligible.

There is a limit to the volume of metal that can be fabricated into the head of a bolt. The maximum length of stock which can be formed into the head is equivalent to seven times the diameter of the rod which is being upset. That is to say, if the diameter of the rod be ¼-inch then it is possible to crush 1¾ linear inches into the head. These tolerances should be followed if "cold shuts" are to be the exception and not

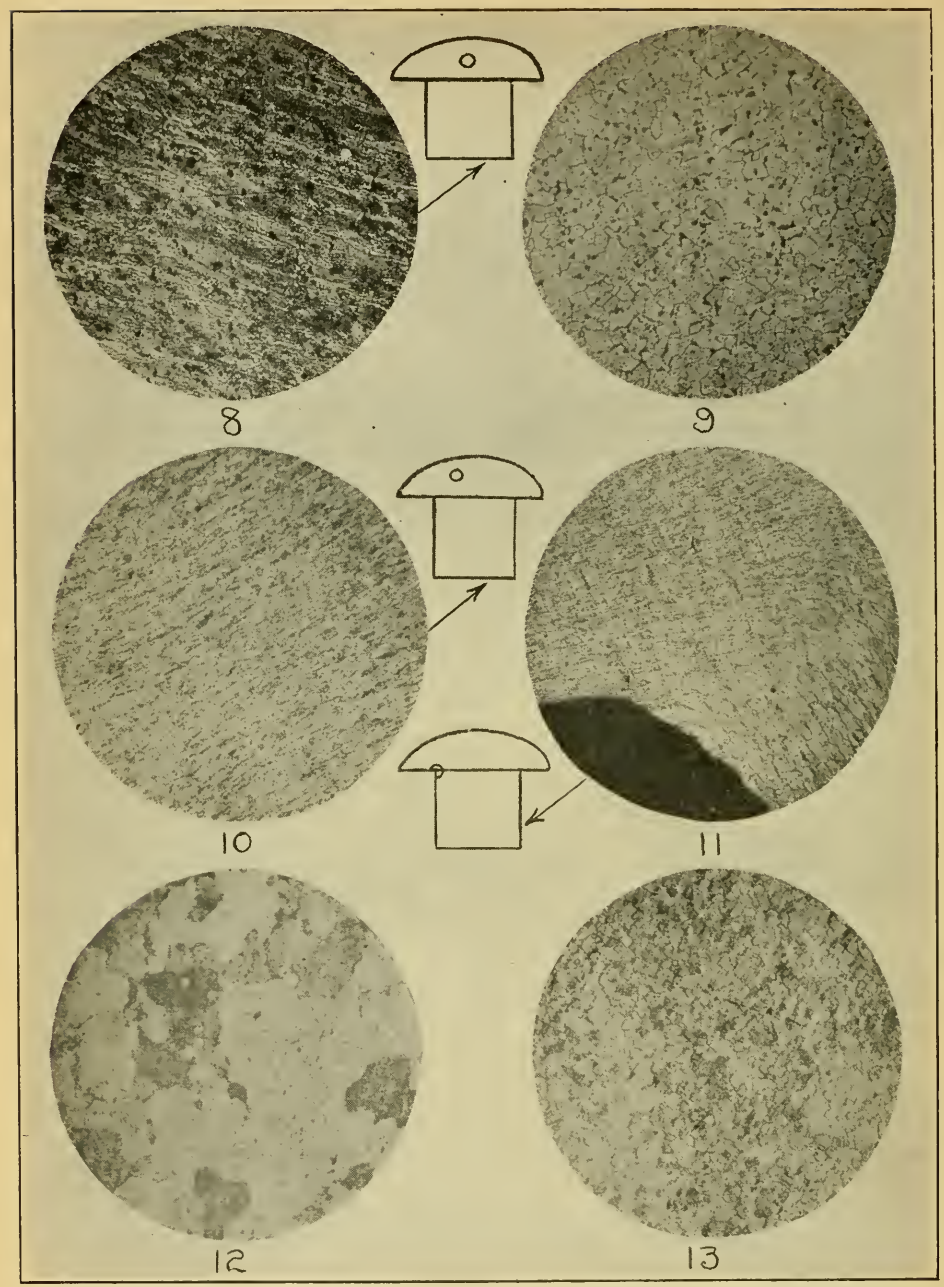


Fig. 8—Another example of effects of cold work, the comprehensive force of the heading operation being responsible for this pattern. Etched and X 100. Fig. 9—This photomicrograph illustrates how grains can be restored to original size and shape by heating specimen above critical range. Etched and X 100. Fig. 10—Slightly strained specimen which would become crystallized if annealed between 1280 and 1380 degrees Fahr. Etched and X 100. The grains have suffered but little distortion. Fiber-like appearance of metal just beginning to show. Fig. 11—Transition from normal grain size to highly strained fibers. Etched and X 100. Fig. 12—Enlarged grain structure produced by annealing a critically strained specimen at 1300-1350 degrees Fahr. Observe the grain growth. Etched and X 100. Fig. 13—Another region from the specimen shown in Fig. 12. Although bolt was annealed in danger zone, a fine grain growth resulted. Etched and X 50

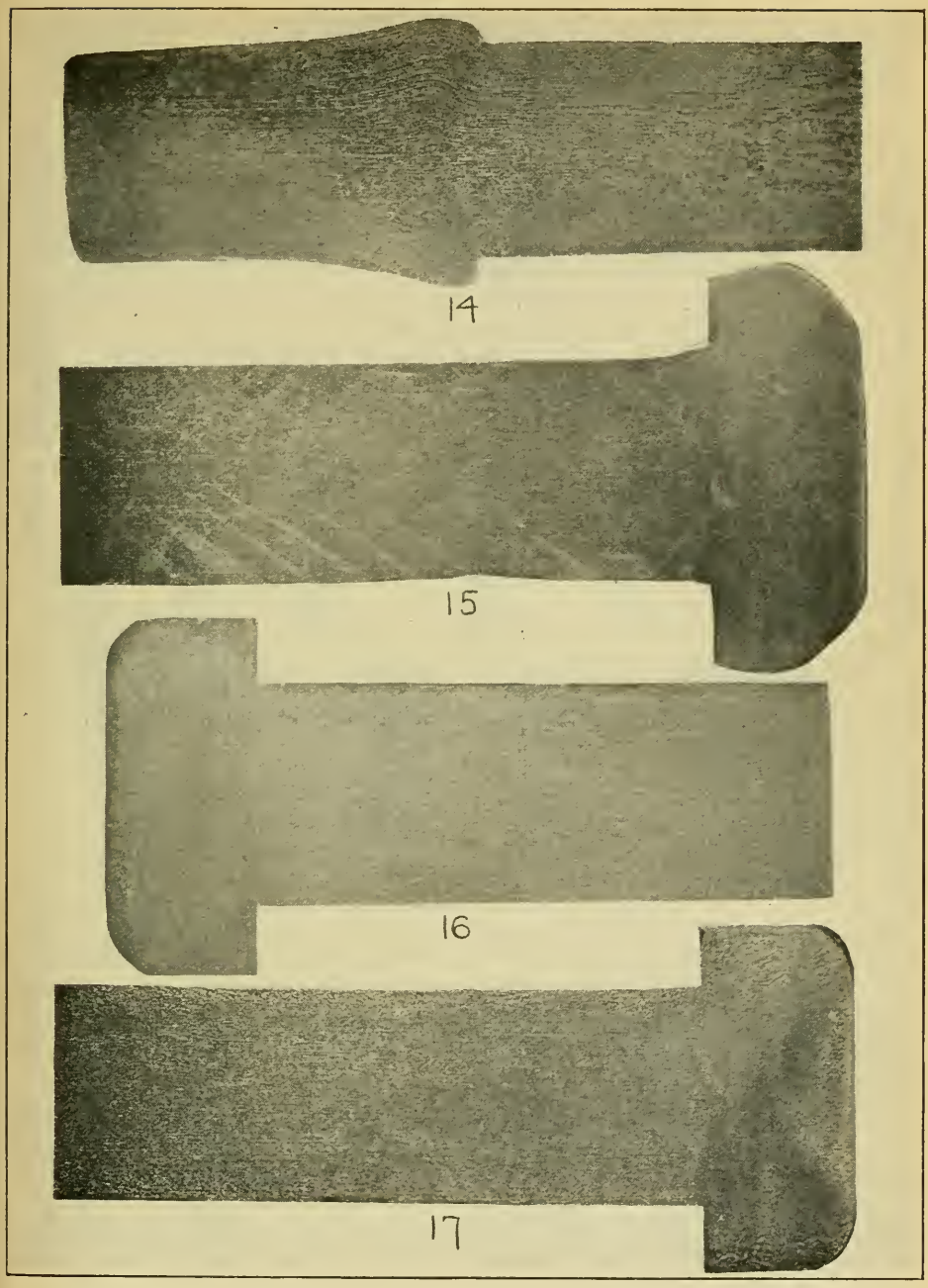


Fig. 14—Macroscopic etching of a bolt after first upset, the strained grain fibers being clearly discernible. Etched and X 3. Contour of strain lines indicates flow of metal. Maximum deformation took place at outer edge of specimen, whereas intensity of distortion increased toward center. Arc at junction of head and shank shows line of demarkation between strained and unstrained areas. Fig. 15—Macroscopic etching after the second upset. Etched and X 3. Greatest strain is in center of head, light areas indicating unstrained metal. The lance-like streaks are caused by polishing. Fig. 16—Another example of the strained condition in the head. Etched and X 3. Area bounded by arcs suffered maximum distortion. The strained fibers resemble a whirlpool. Fig. 17—Same remarks for Fig. 16 apply to this illustration. Etched and X 3

the rule. As shown by Fig. 1, maximum upset limits may be expressed as follows:

$$\text{Volume } ABCD = \text{Volume } EFG$$
$$AB = 7\ BC$$

The reliability of a cold headed bolt is dependent upon the number of blows it received during the fabrication process. The limit of stock which can be compressed into the head by a single blow is two and one-half times the diameter of the rod. Cold headed bolts of commerce are generally subjected to two or three blows. However, there are instances, where four, five, and six blows are required to effect a reliable upset.

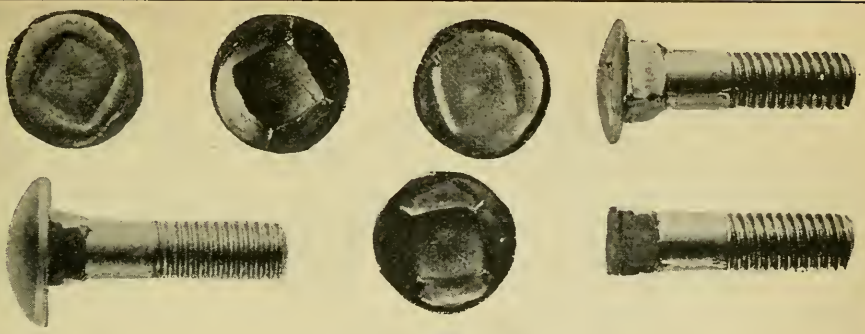
When bolts are cold headed, certain injuries are likely to manifest themselves during the process of fabrication. A "cold shut" is shown in photomicrograph Fig. 2. This defect was occasioned by attempting to upset too much stock. The flow of the metal at one point is clearly shown. Note the isthmus. Another instance of a "cold shut" is shown in the photomicrograph of Fig. 3. Observe the strained condition of the metal in the center of the picture at the extreme left and right. The imperfect flow of the metal is very pronounced.

Photomicrograph Fig. 4 illustrates the manner in which a crack may develop at the junction of the head and the shank. The sharp angle acts as a seat of rupture. Photomicrograph Fig. 5 shows the highly strained appearance of the grains in the vicinity of the rupture. Note the elongated ferrite band which resembles a French curve. Photomicrograph Fig. 6 depicts the banded structure of the strained ferrite grains. Observe that the lines of deformation assume a different direction on either side of the cavity. Moreover, the severely strained areas gradually increase in intensity as the crevice is approached.

Photomicrograph Fig. 7 portrays the elongation of the ferrite and pearlite grains. This print shows the flattened crystals incident to the forming of the head. Fig. 8 is another representation of the effects of cold work. The compressive force of the heading operation is responsible for this pattern. Photomicrograph Fig. 9 shows how the grains can be restored to their original size and shape. It was necessary, however, to heat the specimen above the critical range to remove the last vestige of cold work. Photomicrograph Fig. 10 illustrates a slightly strained specimen which would become crystallized if annealed between 1280 and 1380 degrees Fahr. The grains have suffered a very small amount of distortion. The fiber-like appearance of the metal is just beginning to manifest itself.

Photomicrograph Fig. 11 shows a transition from the normal grain size to the highly strained fibers. Strained and unstrained areas may be found in the same bolt. Photomicrograph Fig. 12 shows an enlarged grain structure produced by annealing a critically strained specimen at 1300-1350 degrees Fahr. Observe the abnormal grain growth. Photomicrograph Fig. 13 illustrates another region of the specimen in Fig. 12. Even though the bolt was annealed in the danger zone, a fine grain growth resulted. The reason therefor is that the metal in the subject area was sufficiently strained to prevent crystallization.

In Fig. 18 is illustrated several exhibits of cold headed bolts which failed in service. The defect may have been occasioned by one or more of the following causes, namely: Omission of heat treatment, excessive quantity of material in the head, carbon segregation, scale, slag inclu-



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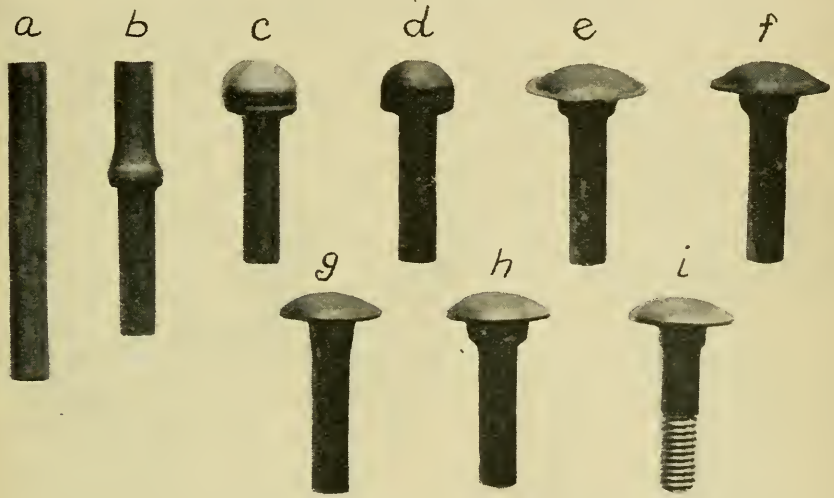

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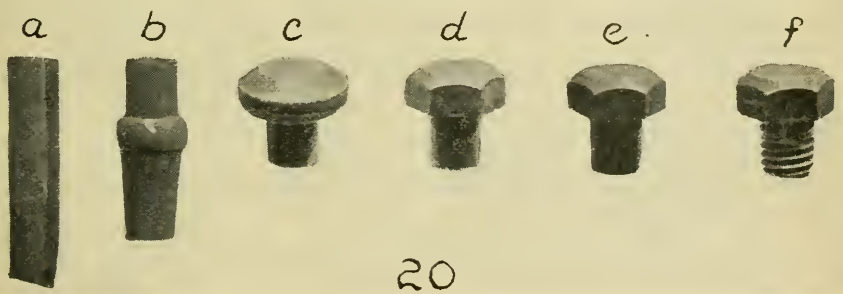

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Fig. 18—Several exhibits of cold headed bolts which failed in service, failure probably being due to omission of heat treatment, excessive material in head, carbon segregation, scale, slag inclusions, ghost lines, or abnormal hardness in rod prior to cold heading. Fig. 19—Evolution of a round head, square shank bolt, cold upset, made from basic cold drawn wire. *A* piece of stock used, *b* first upset, *c* second upset, *d* annealing, *e* reheading or pressing cold, *f* heat treating, *g* trimming, *h* pointing, and *i* threading with a cut thread. Fig. 20—Evolution of a hexagon head tap bolt, cold upset, made from basic cold drawn wire. *A* piece of stock used, *b* first upset, *c* second upset, *d* trimming, *e* annealing and heat treating, *f* threading with a rolled thread

sions, ghost lines, or abnormal hardness in the rod prior to cold heading. Fig. 14 shows a microscopic etching of a bolt after the first upset. The strained grain fibers are clearly discernible. The flow of the metal may be observed by following the contour of the strain lines. The maximum deformation has taken place at the outer edge of the specimen; whereas, the intensity of distortion has decreased toward the center. The arc at the junction of the head and the shank shows the line of demarkation between the strained and unstrained areas.

Fig. 15 shows a microscopic etching after the second upset. The position of greatest strain is shown in the center of the head. That is to say, the light areas indicate the unstrained metal. The lance-like streaks, however, are strains occasioned by the polishing operation. Fig. 16 also shows the strained condition of the metal in the head. The area bounded by the arcs has suffered maximum distortion. The strained fibers resemble a whirlpool in appearance. The same remarks apply to Fig. 17.

Figs. 19 and 20 are photographic views showing the evolution of a cold headed bolt from the rod to the finished product. Fig. 19 shows a round head, square shank bolt, cold upset, made from basic cold drawn wire. *a* shows a piece of material used in making the bolt; *b* the first upset; *c* the second upset; *d* annealing; *e* reheading or pressing cold; *f* heat treating; *g* trimming; *h* pointing; *i* threading. This is a cut thread.

Fig. 20 shows a hexagon head tap bolt, cold upset, made from basic cold drawn wire. *a* shows a piece of material used in making the bolt; *b* the first upset; *c* the second upset; *d* trimming; *e* annealing and heat treating; and *f* threading. This is a rolled thread.

CONCLUSIONS. 1. Various degrees of distortion may be found in the same bolt. Certain regions undergo slight deformation, whereas, other sections undergo extreme distortion.

2. Annealing at 1150 degrees Fahr. will remove the weakening effects of cold work.

3. Irrespective of the degree of cold work, crystallization will not take place below 1280 or above 1380 degrees Fahr.

4. If the temperature of the furnace reaches the hazardous zone, 1280-1380 degrees Fahr., however, crystallization will take place only in those areas which have been slightly strained.

5. Annealing above the critical range, 1650 degrees Fahr., is preferable.

6. In this range of temperature, 1625-1675 degrees Fahr., and regardless of the degree of strain, crystallization will not result.

The successful manufacture of cold headed bolts demands the application of fundamental metallurgical principles. The quality and service of the finished product is therefore dependent upon an adherence to the laws of metallurgy.

NEW DEVELOPMENT ON THE INFLUENCE OF MASS IN HEAT TREATMENT

By E. J. Janitzky

IN THE paper dealing with the influence of mass in heat treatment, read at the Indianapolis convention of the American Society for Steel Treating, and published on page 55 of the October, 1921 issue of TRANSACTIONS, the author confined himself to data taken on a 0.45 per cent carbon steel, as published by the British Engineering Standards association in their report No. 75, dated October, 1920. In this paper it was shown that the hardness-mass formula is

$$B = \frac{nC}{(D-d)} + b$$

in which B is the Brinell hardness of any section.

n is a factor which is constant for each steel of a particular analysis.

C is 14.125, which represents the product of the diameter and surface per pound of steel of any round section.

D is the diameter of the section, the hardness of which is desired.

d corresponds to the vertical asymptote of the curve.

b is the normalized Brinell hardness of the steel.

The object of the present paper is to show that the same general formula that was used for plain carbon steel is applicable to structural alloy steels; also that this formula holds good for the "midway" Brinells, that is, Brinell hardnesses taken half way between the centers and outsides of rounds on their cross sections.

In his previous paper, the author pointed out that n is a factor which is constant for each steel of a particular analysis, and which appears to be, for plain carbon steel, the square of the hardening capacity of the steel in question. As the variable d is a function of the factor n, it is obvious that n is the salient point of the formula.

From experiments soon to be described on two nickel steels, one chrome-nickel steel and from data given by the British Engineering Standards association on a 5 per cent nickel case hardening steel, it became apparent that the factor n for structural alloy steel is twice the square of the hardening capacity, or more generally expressed, a multiple of the square of the hardening capacity, thus, $n = 2\left(\frac{B_M}{b}\right)^2$, in which

B_M is the maximum Brinell hardness which can be developed in the steel.

b is the normalized Brinell hardness of that steel.

Thus, for a 0.32 per cent carbon, 3.25 per cent nickel steel,

$$n = 2\left(\frac{532}{196}\right)^2 = 14.73$$

A paper to be presented at the New York Sectional Meeting, March 3. The author, E. J. Janitzky, is metallurgical engineer, Illinois Steel Co., South Chicago, Ill. In this paper the author has answered the criticisms of Sir Robert Hadfield on his previous paper. These criticisms appear on page 396 of this issue of TRANSACTIONS.

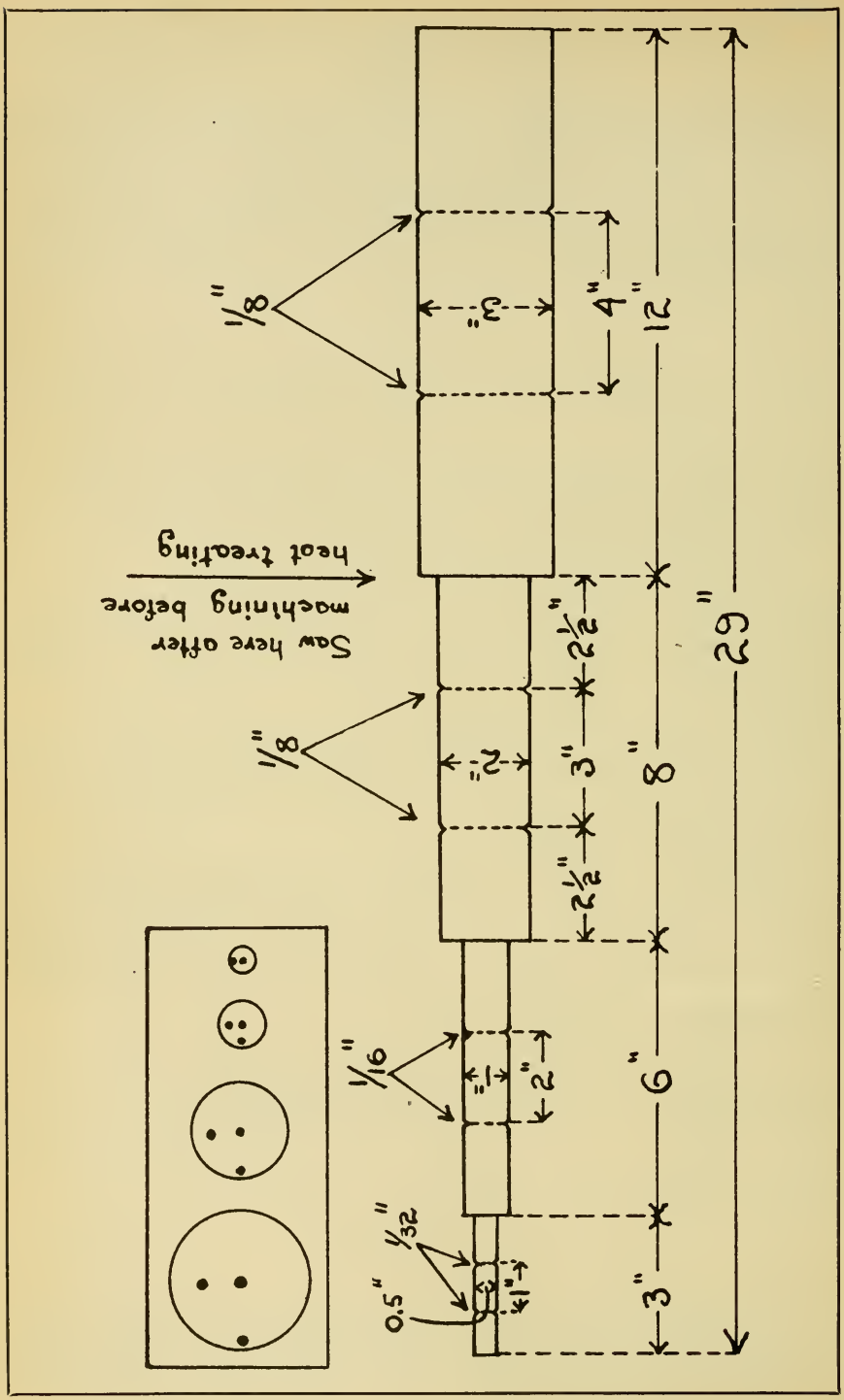

Fig. 1—Standard test specimen for determining the influence of mass in heat treatment. In upper left-hand corner are shown cross sections of the four diameters, indicating the points at which Brinell measurements were taken

For a 0.42 per cent carbon, 3.15 per cent nickel steel,

$$n=2\left[\frac{600}{217}\right]^2=15.27$$

For a 0.34 per cent carbon, 1.20 per cent nickel, 0.56 per cent chromium steel,

$$n=2\left[\frac{555}{217}\right]^2=13.08$$

For a 0.17 per cent carbon, 5 per cent nickel case hardening steel,

$$n=2\left[\frac{388}{187}\right]^2=8.6$$

The specimen used to make these experiments is shown in Fig. 1. It is composed of four sections, each nicked circumferencially as indicated, so that, at the nicks, the diameters of each of the sections respectively is approximately 0.5, 1.0, 2.0 and 3.0 inches. It is best to cut the specimen into two parts before quenching, as this facilitates handling; cutting should be done at the junction of the 2 and 3-inch sections as shown in Fig. 1. After quenching the test pieces should be broken at the nicks and the fractured surfaces ground Brinell hardness numbers should then be obtained on three places of the ground cross sections, thus, close to the surface (circumferencial), midway and in the center. In a 0.5-inch round there will be little or no variation in hardness between the center and the outside, but it is obvious that as the section grows larger this difference becomes greater. Ordinarily after quenching the 3-inch round can be cut with a saw in which case, of course, it is not necessary to fracture it.

It will be noted in all of the following tables that the hardness of the 0.5-inch section is not calculated. The 0.5-inch section is used only to obtain the maximum hardness which can be developed in the steel. A section of this diameter has been chosen to determine the maximum Brinell hardness because it is the smallest one which can be treated practically and brinelled on the cross section. A smaller section is liable to crack in drastic quenching and does not allow the Brinell hardness of it to be obtained.

When a section of steel is quenched, a section so small that it has on quenching a perfect martensitic structure, the quenching of a smaller section will not give a higher Brinell hardness than that obtained in the section just mentioned. Thus, in alloy steels of the structural type, this largest section at which the maximum Brinell hardness can be obtained is on a section having a diameter somewhere between 0.5 and 1.0 inch. Therefore it is not to be expected that the theoretical curve will pass through the point corresponding to the actual Brinell hardness obtained for 0.5 inch.

The following tables give actual and calculated data of the center and midway Brinell hardness of sections whose diameters are shown:

(1). 3.5 *per cent nickel steel quenched in water at* 1450 *degrees Fahr*

The composition of the steel was carbon 0.32, manganese 0.56 and nickel 3.25 per cent.

$B_M=532$, $b=196$, thus

$$n=2\left[\frac{B_M}{b}\right]^2=14.73$$

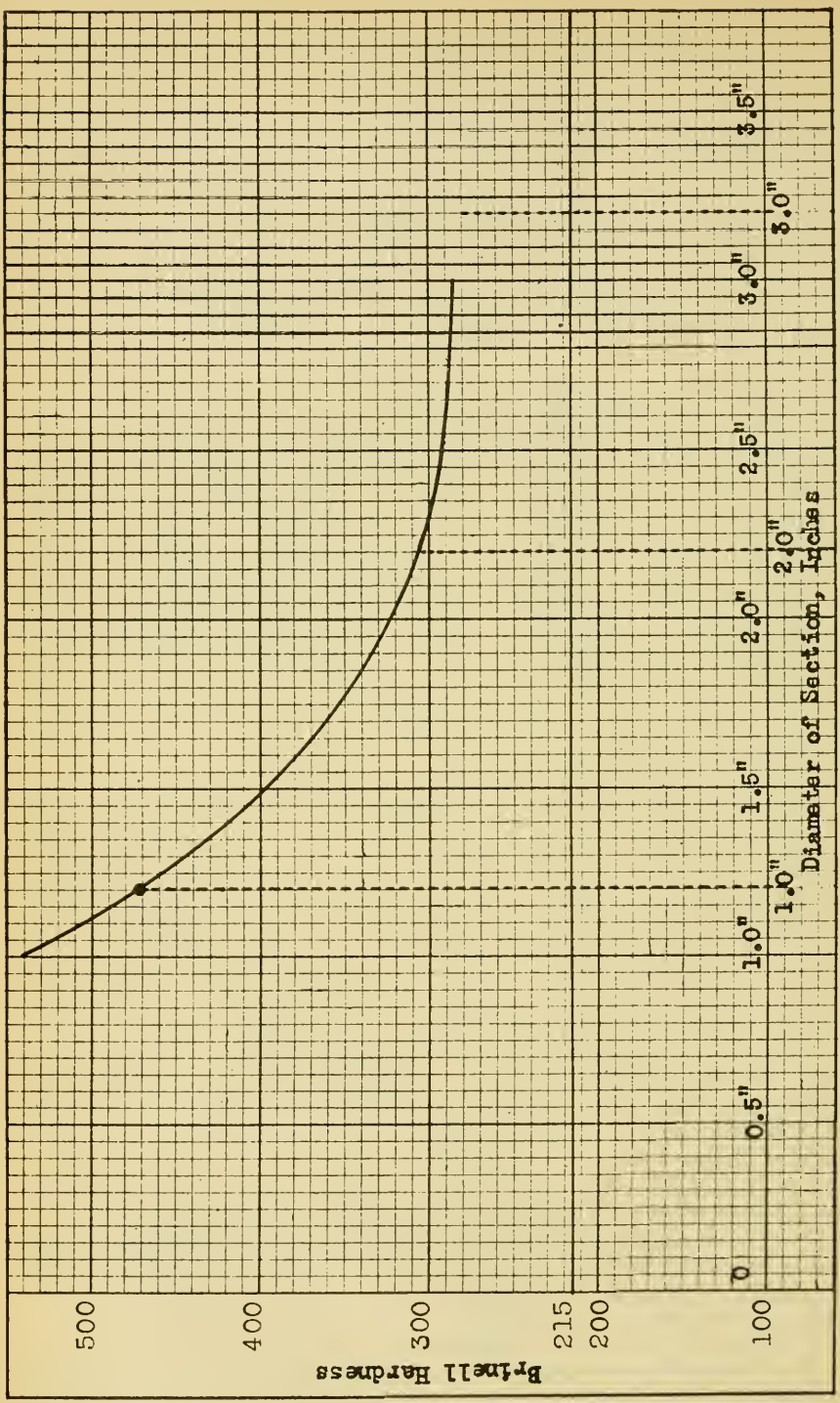

Fig. 2—Water quench curve showing relation of Brinell hardness to diameter of section. After determining the Brinell hardness of a 1-inch section, for example, locate this point on the curve and using the same horizontal scale, read off the Brinell hardness of other sections

Center Data

$$\text{for 1 inch, } d=1 - \frac{(14.125)\quad(14.73)}{430 - 196}=0.111$$

$$B=\frac{(14.125)\quad(14.73)}{D - 0.111}+196$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	532	...
0.73	...	532
1.0	430	430
2.0	302	306
3.0	348	268

Midway Data

$n=14.73$

$$\text{for 1 inch, } d=1 - \frac{(14.125)\quad(14.73)}{477 - 196}=0.260$$

$$B = \frac{(14.125)\quad(14.73)}{D - 0.260}+196$$

The following results were obtained::

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	532	...
0.879	...	532
1.0	477	477
2.0	302	315
3.0	255	272

(2). 3.5 *per cent nickel steel quenched in water at* 1450 *degrees Fahr.* The composition of the steel was carbon 0.42, manganese 0.61 and nickel 3.15 per cent.

$B_M=600$, $b=217$, thus

$$n=2\left(\frac{B_M}{b}\right)^2=15.27$$

Center Data

$$\text{for 1 inch, } d=1 - \frac{(14.125)\quad(15.27)}{540 - 217}=0.332$$

$$B = \frac{(14.125)\quad(15.27)}{D - 0.332}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	600	...
0.896	...	600
1.0	540	540
2.0	321	346
3.0	286	298

Midway Data

$n=15.27$

$$\text{for 1 inch, } d=1 \quad \frac{(14.125)\quad(15.27)}{555-217}+0.362$$

$$B=\frac{(14.125)\quad(15.27)}{D-0.362}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	600	...
0.925	...	600
1.0	555	555
2.0	340	349
3.0	302	300

(3). *Chrome-nickel steel quenched in water at* 1535 *degrees Fahr.*

The composition of the steel was carbon 0.34, manganese 0.50, nickel, 1.20 and chromium 0.56 per cent.

$B_M=555$ and $b=217$, thus

$$n=2\left(\frac{B_M}{b}\right)^2=13.08$$

Center Data

$$\text{for 1 inch, } d=1 \quad \frac{(14.125)\quad(13.08)}{477-217}=0.289$$

$$B=\frac{(14.125)\quad(13.08)}{D-0.289}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	555	...
0.836	555	555
1.0	477	477
2.0	340	325
3.0	286	285

Midway Data

$n=13.08$

$$\text{for 1 inch, } d=1 \quad \frac{(14.125)\quad(13.08)}{495-217}=0.336$$

$$B=\frac{(14.125)\quad(13.08)}{D-0.336}+217$$

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	555	...
0.883	...	555
1.0	495	495
2.0	340	328
3.0	302	286

(4) *5 per cent nickel case hardening steel quenched in water at* 1580 *degrees Fahr. and requenched in water at* 1400 *degrees Fahr.* (*From British Report*).

The composition of the steel was carbon 0.17, manganese 0.34 and nickel 6.0 per cent.

$B_M = 388$, $b = 187$, thus

$$n = 2\left(\frac{B_M}{b}\right)^2 = 8.6$$

$$\text{for 1 1/8 inch, } d = 1.125 - \frac{(14.125)\quad(8.6)}{363 - 187} = 0.435$$

$$B = \frac{(14.125)\quad(8.6)}{D - 0.435} + 187$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.6875	388	...
1.04	...	388
1.125	363	363
1.50	321	300
2.125	277	259

In regard to the formula, it would appear that the Brinell hardness of the steels in the annealed state should be taken for b; however, as we do not deal with sections of indefinite diameter, the value used for b is that of the steel in the normalized condition. It seems to answer the purpose of the formula better for engineering purposes.

It is also obvious that in the case of specimens drawn or quenched in different media, the same procedure should be followed as that in this paper. It is not necessary to calculate the Brinell hardness for sections drawn or quenched in different media, if the water quench curve for that particular steel is at hand. It is only necessary to obtain the Brinell hardness of say, a 1-inch section, fix this point on the water quench curve and using the same scale, read off the Brinell hardnesses of other sections, as shown in Fig. 2.

Attention is called to the fact that the results given in this paper are not averages of a number of tests. They represent a single result of one investigator. If this experiment would be carried out by a number of investigators and the results averaged, still closer checks between the actual and calculated values would be expected.

In concluding the author wishes to state that whereas the first paper was a demonstration of the hyperbolic tendency of the curve of the physical properties of steel sections of the same analysis, this paper endeavors to cover the practical application when one is confronted with the mass problem.

The author wishes hereby to express his appreciation for the assistance rendered by H. Blumberg.

CALITE—A NEW HEAT RESISTING ALLOY

By G. R. Brophy

A FRESHLY cut surface of aluminum, like all metals, will show a bright lustrous surface, but after a very short time in the atmosphere becomes dull. On longer exposure little change takes place in this strongly adherent coating. This is recognized as a protective coating of oxide. Aluminum when alloyed in solid solution with other metals still retains this property of oxidizing readily and lends this property to the alloy.

Advantage of this property was taken a few years ago when calorizing was developed. This process, which has been described many times, consists of coating metals with aluminum at high temperature, actually forming a surface alloy which is highly resistant to oxidation at high temperature and to many forms of corrosion. Calorizing is not suited for work above 1832 degrees Fahr., due to the rapid diffusion of aluminum and the consequent lowering of the surface aluminum content to the point where breakdown under oxidation occurs.

A homogeneous alloy made by melting aluminum with iron naturally will show no such diffusion on subsequent heating, and provided the aluminum content is sufficiently high, the alloy will resist oxidation at temperatures nearly up to its melting point. Unfortunately, on repeated heating and rapid cooling, or uneven heating, these alloys crack badly and no homeopathic doses of any third metal tried—and nearly all were tried—helped this condition. The hot metal when the least moisture touched it acted like hot glass, flying to pieces.

The low expansion of high nickel steels together with the fact that aluminum and nickel form a high melting compound led to investigating the promising ternary alloys of aluminum, nickel and iron. Therefore, keeping aluminum at a minimum and substituting nickel for iron in various percentages, a series of alloys was obtained which showed increasingly good properties. However, when nickel reached 15 per cent the alloy was soft and lost nearly all its resistance to oxidation. This was probably due to the formation of the high melting compound corresponding to the formula NiAl, which, while highly resistant to oxidation itself, robbed the iron of its protection and allowed the iron to scale badly. Further additions of aluminum and nickel in proportions other than that of the above compound finally gave an alloy which was strong; would stand shock, hot or cold; could be quenched repeatedly; and was highly resistant to oxidation. A few further refinements gave the alloy which was finally adapted and which we call calite.

Manganese and silicon above 0.75 per cent both tend to decrease resistance to oxidation, but with care in melting, no trouble is experienced. Carbon increases brittleness and should be kept as low as possible and easily runs under 0.05 per cent. On account of the ease with which SiO_2 slags with aluminum, the melting must be done in a basic furnace. Also the ladle used must have a basic lining.

Basic Heroult type furnaces are used with good success. Steel scrap is first melted down and decarburized; slag is removed and nickel is

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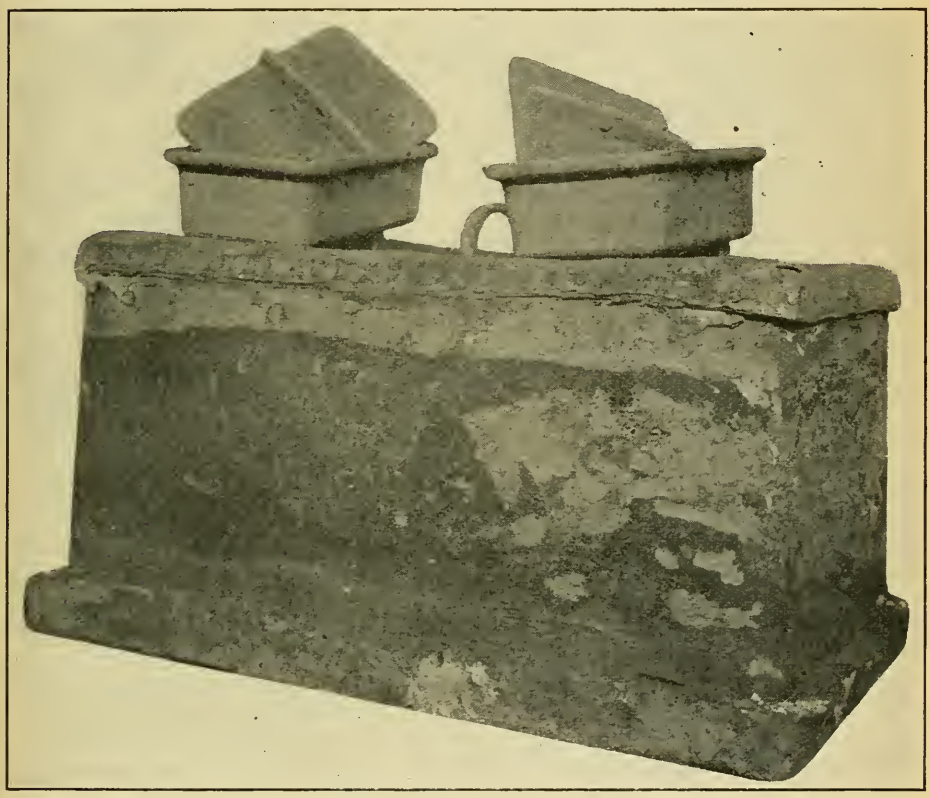
A paper to be presented at the New York Sectional Meeting, March 3. The author, G. R. Brophy, is metallurgical engineer, industrial furnace department, General Electric Co., Schenectady, N. Y.

added and a new slag made. When all is thoroughly deoxidized, the final slag is removed and scrap calite added to the extent of 25 per cent of the melt and dissolved. The melt is then poured in a preheated ladle containing the required amount of molten aluminum. As this alloying takes place, an exothermic reaction occurs of sufficient intensity to dissolve additional scrap, and up to the present, scrap amounting to 15 per cent of the melt has been dissolved with sufficient residual heat to necessitate holding in the ladle several minutes. The ladle is bottom poured



Annealing boxes made from calite, having run 1500 heat hours without warpage or growth

so that the time of holding allows all oxide to float and nothing but clean metal to be poured.

The metal runs freely, and sections of 3/16-inch have been cast successfully. Any casting which can be made of steel can be made of calite. The shrinkage being the same as steel, the same precautions must be taken.

Calite resists oxidation up to 1300 degrees Cent. (2372 degrees Fahr.) but 1200 degrees Cent. (2200 degrees Fahr.) is recommended for indefinite service. The protective oxide formed is tight and does not snap off even on quenching from high temperatures. Quenching after 100 hours at 1200 degrees Cent., calite lost but 0.03 gram per square centimeter ex-

posed, while the best heat resisting base metal alloy other than calite lost 0.56 gram under the same conditions. The same samples were run at 1300 degrees Cent. for an additional 25 hours. Calite lost 0.003 gram, the other 0.09 gram per square centimeter exposed. From these figures it appears that calite is 20 times as resistant at 1200 degrees Cent. and the only base metal alloy to stand at temperatures higher. At 900 degrees Cent. or ordinary operating temperatures the loss per square centimeter was measured in 1/10 milligram, or for all practical purposes no loss.

Calite is practically noncorrosive. Samples have been polished and run in a spray of saturated sea salt solution at 100 degrees Fahr. for 200 hours and at the end of this time still retained the perfect polish. So called stainless steel will last but a few hours in this test. For fittings exposed to salt atmosphere calite should be excellent.

Twenty-five per cent sulphuric acid dissolves calite rapidly; hydrochloric acid slowly and nitric hardly at all. Forty-eight hours in 25 per cent nitric acid, the metal lost 0.0004 gram per square centimeter exposed. Acetic acid has no effect. Molten carbonates, chlorides, nitrates, cyanides, Pb, Zn, Sn, type metal, sulphur and sulphur vapor do not attack calite. SO_2 gas at 900 degrees Cent. has no attack. Fluxes such as cryolite, borates and silicates attack calite rapidly.

In general, the physical properties are as follows:

Melting point, degrees Fahr	2777
Softening temperature, degrees Fahr	2500
Working temperature, degrees Fahr	2200-2370
Specific gravity	7.03
Weight per cubic inch, pounds	0.25
Brinell hardness, annealed	286
Sclerescope hardness, Annealed	40
Thermal conductivity, per cent of iron	25
Transverse stress, 1-inch square bar, pounds per square inch	4250
Tensile stress, pounds per square inch	36,800

Calite cannot be machined in the cast condition, nor cut with oxy-acetylene. Any change of dimension or finish must be done by grinding. It is more resistant to oxidation at high temperatures and will stand higher temperatures than any base metal alloy tested. Its first cost is low and operating cost lower than other nonoxidizing alloys. Boxes shown in the accompanying illustration have been run for 1500 heat hours and will be seen to be in the best condition. Measurements of these boxes show no warpage or growth. The oxide coating is no heavier now than after the first heat.

MAGNETIC TESTING OF SMALL CASE HARDENED CHAIN

By A. V. de Forest

THE problem of determining the depth of case in carbonized and case hardened work is one in which the customary nondestructive methods of test are difficult or impossible to apply. In some cases, the surface hardness may be estimated with a scleroscope or a file, or under favorable conditions a Brinell test can be made, but in general, none of these tests is satisfactory on this class of material. A magnetic method which has been applied successfully to a particular product therefore may be of some interest.

The product under discussion is small steel chain in various diameters of wire from 0.192 up to 3/8-inch, and in short lengths of from 5 to 15 inches. It is used as the cross member in automobile tire chains, where it is exposed to the wear of hard roads, and to the shock of pounding over car rails and cobble stones. The result is that if the case is too thin it wears out too fast, and if too thick, it breaks even before the soft chain has worn out. Fortunately, there is an intermediate condition from which reasonable service may be expected.

In order to determine this condition for maximum service, a test is needed in which any variable which increases the brittleness of the chain will show itself in the direction of increased depth of case. In the present instance, the magnetic property under observation varies with the quenching temperature and the structure of the chain in the desired manner.

Resistance to wear and the resistance to shock are in general inversely proportional to each other, and the point of maximum usefulness is highly indeterminate. The final test, the mileage run on the road, is so full of accidental variations, that the average of a large number of records must be considered. This has so far prevented a close study of the effect of small changes in structure. If we consider the depth of case as the only variable, and make the chain from the same wire, carbonize at the same temperature in the same compound for different times, and quench all our chains from the same temperature, we obtain magnetic readings proportional to the depth of case. If then a set of these chains, ranging from thin case to thick are taken off after the first to break has worn through it will be found that the wear is very closely proportional to the magnetic reading. This is shown in the picture, and holds true regardless of the weight of car used or the speed and nature of the road. When the chains are run until all are broken and the mileage of each is considered, it is found that in general the low reading and the high reading have given about the same result; and somewhere between the two is the longest lived chain. The softer the road, and the lighter the car, and the slower it is driven, the closer will the best chain come to the high reading, or deep case end of the scale. However, this hard end is the more dangerous, for a chain overhard for the use to which it is put may break in a few miles, while the too soft chain will wear out only after a fair length of travel.

The magnetic test, therefore, is used to determine when the chain is unnecessarily soft or dangerously hard. This latter figure is derived en-

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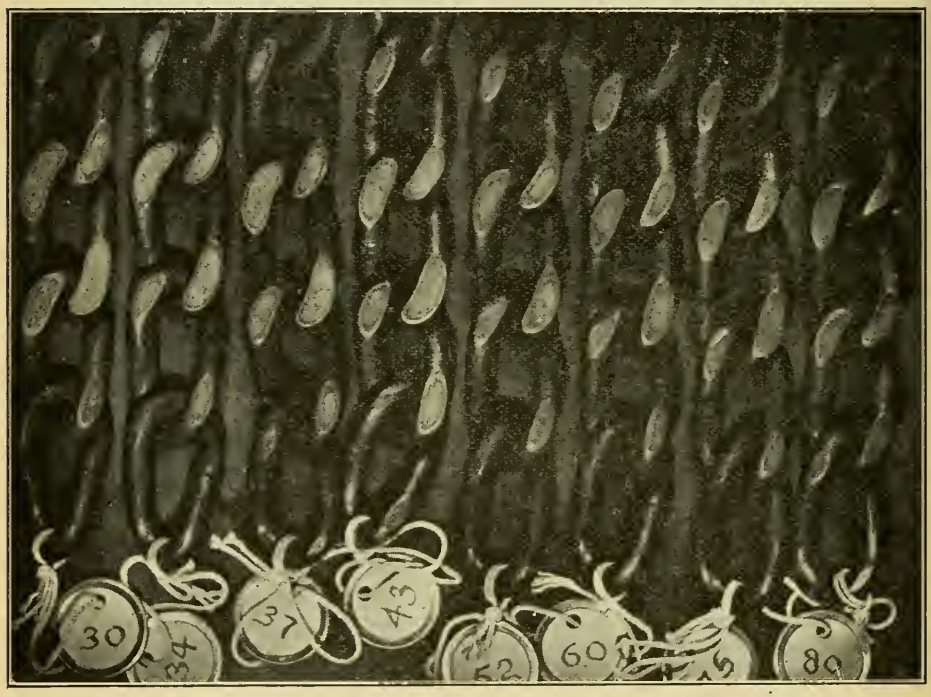
A paper to be presented at the New York Sectional Meeting, March 3. The author, A. V. de Forest, is research engineer, American Chain Co., Bridgeport, Conn.

tirely from experience, and is only an estimate to meet the worst conditions. It is not yet practical to make chain to suit the temperament of the driver of each car and the paving of the streets he uses, but some day chains may come like tooth brushes, hard, soft and medium, in properly labeled packages.

Major variables involved are the size of chain; the depth of case; the carbon content of the case and its distribution; the composition of the core; the structure of case and core, as determined by the carbonizing temperature and the heat treatment. The effects of each of these



Specimens of steel automobile skid chain cross links which have been subjected to wearing tests to determine the necessary depth of case

factors on the magnetic result have not as yet been too accurately determined. The following points, however, may be of interest. In the carbonized chain, slowly cooled or normalized, the magnetic reading is closely proportional to the depth of case. Here the core is pretty regular in composition and the carbonizing material the same in each instance. When reheated and quenched the magnetic result is higher the higher the quenching temperature. Furthermore, the magnetic result is higher for a coarse structure as quenched from the pot, than for a finer structure quenched from the same temperature, as is obtained by reheating and requenching. So far the magnetic result has given a pretty close idea of the "brittleness" of the chain whatever that may mean. If now another variable is brought in, the drawing temperature results are not as good. A draw at 450 degrees Fahr. lowers the magnetic reading

more than it affects the life of the chain. At 550 degrees Fahr., the same thing is true. However, in practice, drawing has not so far proved generally advisable so this effect is not a factor in this case.

The magnetic apparatus itself is a simple form of inductance bridge, operating on 60-cycle commercial current. A rather peculiar type of separately excited galvanometer is used as an indicator. A small rheostat and ammeter control the current to operate. In this case about 0.2 amperes at 110 volts are used. Resistance coils control the sensitivity of the instrument, and the deflections can be adjusted to any desired limits. An adjustable resistance is used to balance the galvanometer, and is altered to compensate for different sizes of specimen, or to change the scale of the instrument. Either deflection or null method can be used. The deflection method is ordinarily sufficiently accurate. The magnetizing coil may be of almost any size. The one in question will operate on 1/16-inch wire, chain formed of ⅜-inch wire, or bar stock up to 1¼-inch in diameter. The whole outfit is easily portable and needs no setting up beyond connection to an alternating current lighting circuit.

It has been found that the introduction of a rapid and nondestructive test enabled the testing of a vastly greater number of samples, and a much closer control over the factors affecting the problem. It enables experiments to be conducted intelligently on time of heat, temperature, shape and material of pots or retorts, method of packing, arrangement of furnace, carbonizing mediums, and all the troubles giving rise to the far famed irregularities of case hardened work. Also by giving quantitive results, it allows a better interpretation of service tests on the finished product.

Last but perhaps most important of all, it affords justice to the heat treating force, for careful and intelligent operation can be accurately appreciated and carelessness properly censured. The result is that much greater interest is taken in the quality and uniformity obtainable under routine conditions, and all concerned with this frequently abused department can share the satisfaction of a good job well done.

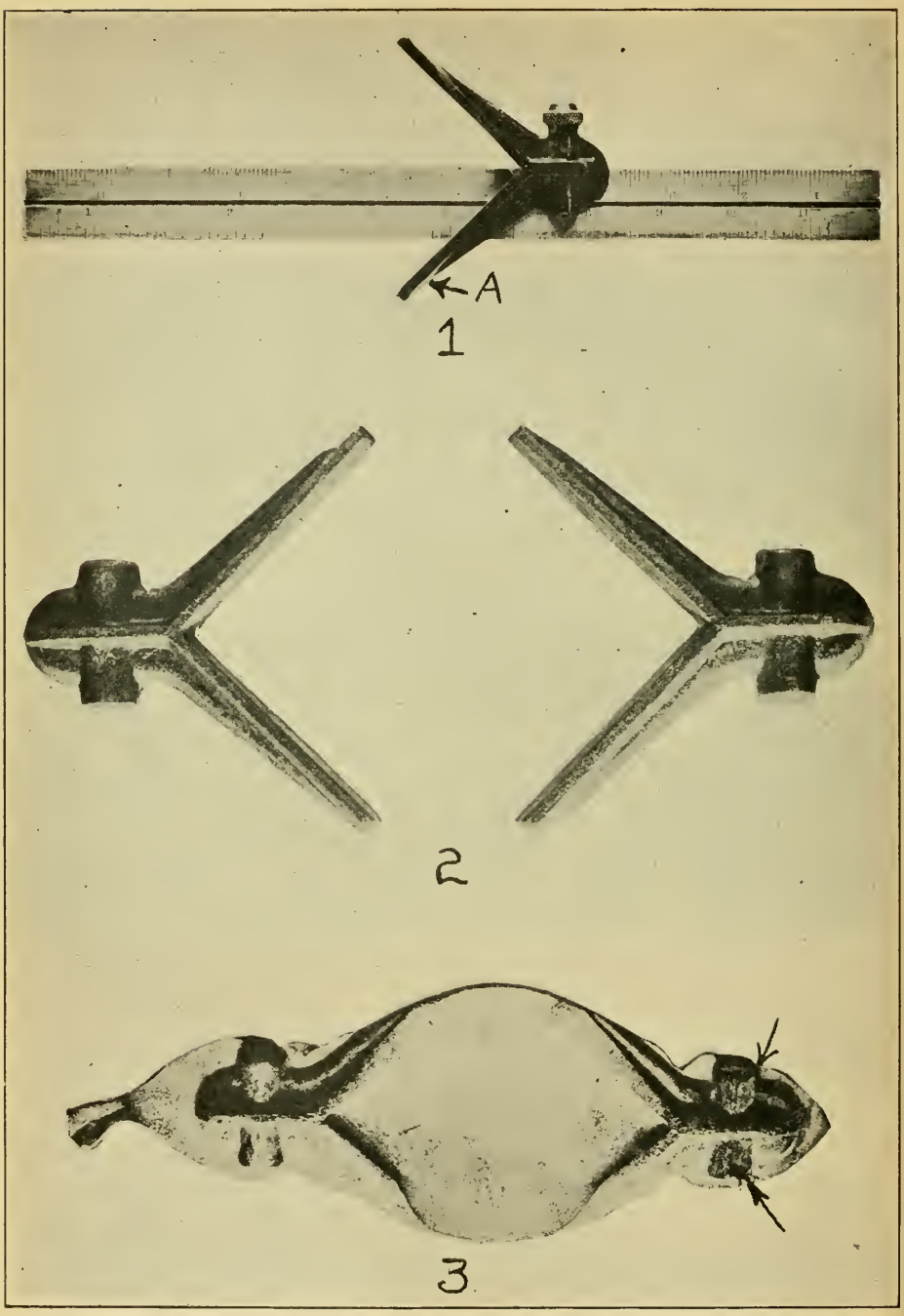


Fig. 1—Photograph of a mechanics square, the portion marked *A* being the part of the forging under discussion. Fig. 2—It has been found desirable to forge the piece double in the die as shown in this illustration. Fig. 3—The third step in the forging operation, the arrows indicating the formation of the boss

PERFECTING A DROP FORGING

J. H. G. Williams

PURCHASERS of drop forgings often are of the opinion that once the dies are made, it is a simple matter to produce sound forgings, and the manufacturer often is of the opinion, privately of course, that the purchaser is unreasonable because he cannot understand how difficult it is to produce sound forgings, once the dies are made.

This disturbing situation is due to a lack of knowledge of the principles underlying the flow of metal in the plastic condition. Scientific research on the subject has not been linked up with the practical applications. The individual die makers have accumulated through experience an empirical knowledge. Every set of drop forge dies is largely the expression of an individual opinion as to the flow of plastic metal. Feeling that it is advantageous sometimes to study the reverse side, the accompanying set of photographs is exhibited to illustrate how metal did not flow in the manner originally planned.

Fig. 1 is a representation of a mechanics square. That part marked *A* is the forging under discussion. The piece is forged double as shown in Fig. 2. There are at least two reasons for arranging to forge double in this manner: The rate of production is increased; and there is less weight of metal involved in the manufacture of two forgings by this arrangement, than would be if the two forgings were made singly. The flash or excess metal surrounding the outside of the forging is trimmed away and excess metal in the center is punched out, which leaves two forgings supposedly ready to machine for use.

At this stage of manufacture, the forgings are inspected, and during the production of the first few dozens, certain defects called "laps" and "cold shuts" were discovered, the causes and elimination of which constitute the basis of this paper. Low carbon steel 1½ x ½-inch is used as raw material. As originally made, the first operation consisted of redistributing the metal from the uniform section shown in Fig. 4, to that shown in Fig. 5. It will be observed in Fig. 5 that there is a mass or bunch of metal at *A* and *B* corresponding approximately to the positions that the bosses will occupy in the forging.

There are very substantial reasons for this preliminary distribution of metal. First, the productive life of the die blocks is prolonged by removing from the impressions the burden of this mass movement of metal. Second, by distributing the metal in masses to the approximate position required by the impressions in the dies, the formation of a true, sound forging is promoted. Fig. 3 shows the next forging step. It will be observed that this operation is an extension of the preceding operation. The original uniform section of the bar has now become a nonuniform section in which the metal has been distributed as masses into positions from which the forging impression can work or mold these masses into the desired finished shape. Particular attention is called to the boss indicated by the arrow. The formation of a forging defect, known as a "lap" is in progress.

The section of the partially formed forging as it comes from the first

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A paper to be presented at the New York Sectional Meeting, March 3. The author, J. H. G. Williams, is assistant works manager, Billings & Spencer, Hartford, Conn.

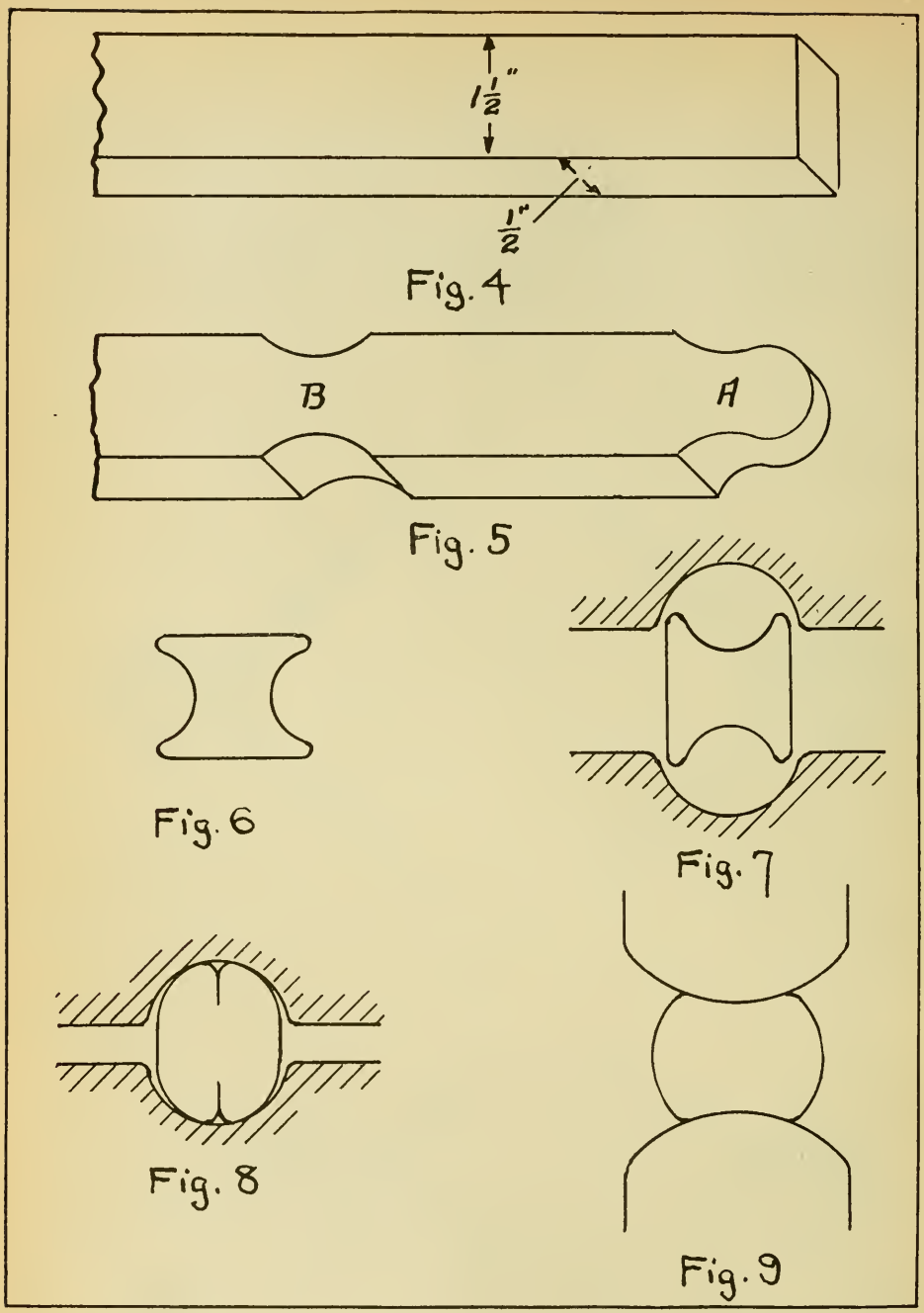


Fig. 4—A specimen of the stock used in producing the drop forged part. Fig. 5—The uniform section of Fig. 4 is redistributed as shown, metal being massed at *A* and *B* at the approximate positions the bosses will occupy. Fig. 6—The section of the partially formed forging as it comes from the first or "edger" operation. Fig. 7—For the second or "rough blank" operation, the piece is given a quarter turn. Fig. 8—The lips of the cup-like section shown in Fig. 7 are lapped over by the pressure of the dies. A photograph of this operation is shown in Fig. 3. Fig. 9—To eliminate the lapping effect, the edger may be rounded off somewhat as shown

or "edger" operation is something like Fig. 6. When placed under the dies for the second or "rough blank" operation, it is given a quarter turn so that the cup shape faces the impression, Fig. 7. The action of the dies upon the lips of the cup-like section is to lap them over somewhat as shown in Fig. 8, and it was the photographic representation of this action that was illustrated upon Fig. 3.

In order to eliminate this lap, it is necessary to modify the impression which changes the shape of the bar stock. Because this impression is sunk in the edge of the dies, both the operation and the impression, are referred to as the edger. It is clear enough that the desired redistribution of metal must be accomplished without the formation of the cup shape section of Fig. 6. The edger may be rounded off somewhat, forming a section somewhat resembling Fig. 9, and this latter section will be found to operate under the rough blank impressions without the formation of a forging defect.

As a matter of fact, these laps were eliminated by omitting the use of the edgers. It was found after making the first dozen forgings, that the bar stock could be placed between the "breakdown" impressions, and produce the shape shown in Fig. 3, without the necessity for any previous preparation of stock, and without the formation of any laps. Fig. 10 is a close up of the laps just described. The rough blank shown in Fig. 3 is transferred to the finishing impressions, and emerges in the form shown in Fig. 11. This forging is ready to have the flash trimmed off and the center punched out.

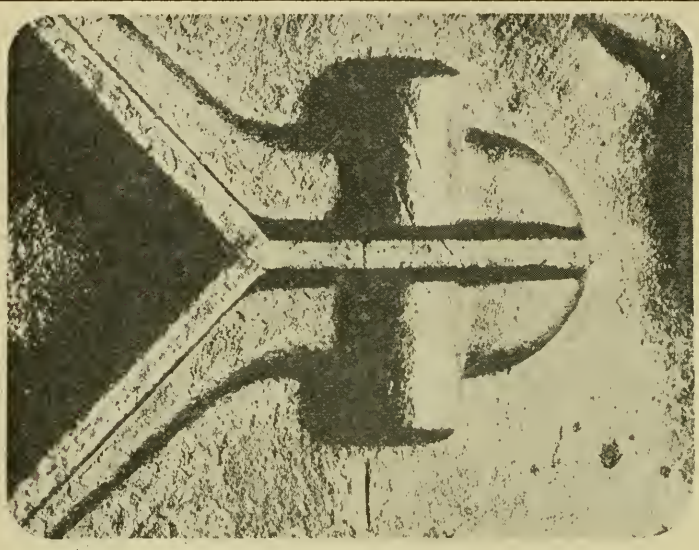
Another interesting and at the same time instructive type of defect appeared at points *A*, Fig. 11. After trimming, the forging was found to be split at the flash line. Defects of this nature are common with piped stock, but an extended examination of the raw material demonstrated that the bar stock was sound and homogeneous. Figs. 12 and 13 show a magnified view of the metal in the vicinity of the split. The heavy black streak is iron oxide. It was noticed that this split was just above the flash line instead of in the center of the flash line as would be expected if the defect were due to the material itself.

Fig. 14 shows a section of the forging that explains the formation of the defect. Any section of the blank must contain a greater area than the corresponding section of the finished piece. The forging operation consists of forcing out the excess metal while forcing the required metal into the shape contained by the impressions. As a direct result, this excess metal must flow sideways into the flash, that is, the excess will flow toward the outside, and toward the inside of the forging.

The laps in the center at *A* Fig. 14 illustrate waves or undulations of excess metal that traveled toward the center under the effect of each blow of the hammer, where they were folded over and compressed. Now, when this central web of metal is compressed by the blows of the hammer, the metal has no opportunity to flow elsewhere than to the outside, and in so doing must pass through the arms of the forging. The effect of a flow such as just described is to fold the surface into the forging proper. This condition is shown by the black spots just above and below the flash on the right side of the forging in Fig. 14, and also by the black streak in the left side. When the excess metal is trimmed off, the

forgings will show splits or separations of metal at *B*, just above the flash line.

Several methods are used for removing the conditions which promote the formation of these defects and all are based upon the principle of providing a central space into which the excess metal may flow. For instance, the center can be punched out, or the thickness of the cen-



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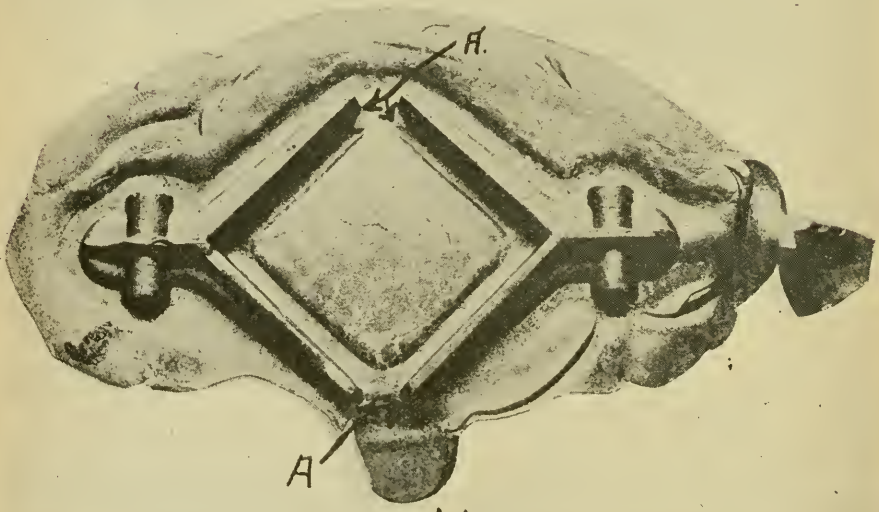

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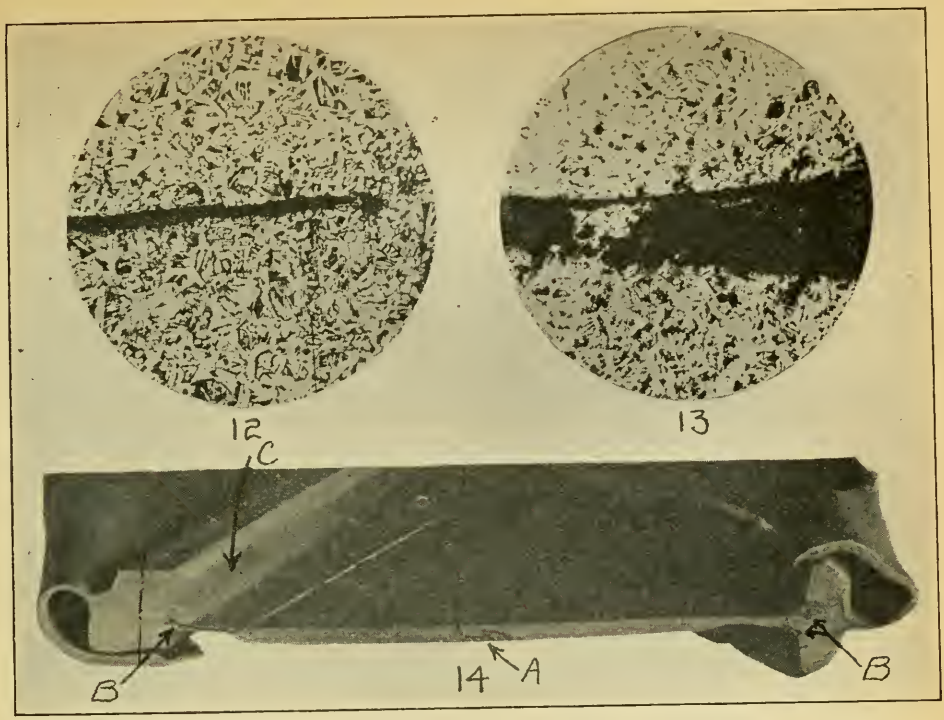
Fig. 10—A close up of the laps formed as shown in Fig. 8. Fig. 11—After trimming, the forging was found to be split at the flash line as indicated by *A*



Figs. 12 and 13—A magnified view of the metal in the vicinity of the split shown in Fig. 11. X 100. The heavy black line is iron oxide. Fig. 14—A section of the forging which explains the formation of the split defect. The illustration is about twice actual size

tral web may be forged undersize previous to finish forging, or the bosses in the finish impression may be hollowed out.

Fig. 14 also illustrates one more forging defect, known as "mismatching". Referring to the arm on the left, it is obvious that the lower or bottom part of the forging is not symmetrical with the upper or top portion. A defect of this character is due to the upper and lower die blocks being slightly out of alignment. This photograph also demonstrates that the upper die impression shaved the edge of the blank, and formed the lap which is so clearly evident. While the lap was being folded over and pressed down, the metal in the central web was flowing toward the outside, and the inner surface of the lap and the upper surface of the web were pushed into the interior of the forging as indicated by the black streak at *B*.

The first forging produced after a hammer set up is carefully examined for forging defects, and adjustments or alterations are made to overcome the objectionable features. By carefully checking up each forging during this period of adjustment, the dies are finally brought into a condition such that a continuous run of perfect forgings may be produced.

COMMENTS ON E. J. JANITZKY'S PAPER, "A CONTRIBUTION TO THE PROBLEM OF THE INFLUENCE OF MASS IN HEAT TREATMENT

By Sir Robert Hadfield

THE paper, "A Contribution to the Problem of the Influence of Mass in Heat Treatment," by E. J. Janitzky, which was published on page 55 of the October, 1921 issue of TRANSACTIONS deals with an interesting point. There is no doubt that if the mass effect in heat treatment can be made to lend itself to calculation, the data so obtained will be very useful.

Mass effect operates mainly in two different connections: (a) By influencing the time necessary to heat an article through to its center to an even temperature in the furnace; and (b) by influencing the rate of heat extraction in cooling operations, and thereby the hardness and other physical qualities of the material. It is the latter feature to which Mr. Janitzky has applied himself. By way of comment on his method of treatment of the subject, the writer would make the following remarks.

The initial basis of his calculations shown in formula (2), page 57, is a physical one. It is questionable, however, whether it is right to assume that the hardness, or the increase of hardness produced by rapid cooling (B-b), has a linear relationship with the surface per pound of steel. In order to establish a scientific formula, and not merely an empirical one, it would be necessary to look more closely into this relationship.

The introduction of the term d renders the working formula (4) entirely empirical, because no physical significance can be assigned to this term.

Empirical formulas, however, often can be of service in metallurgical calculations providing the constants obtained are either invariably the same, or a definite constant can be assigned for any particular set of conditions including the type of material worked with.

In Mr. Janitzky's calculations the value of d varies, and if it is desired to apply this hyperbolic formula to any particular case it is necessary to ascertain the values both of b and d for that particular case, which can only be done by previously having at least three experimental observations with one particular treatment on three different sizes of bars. A fair estimate might then be made of the hardness to be obtained from any other size of bar within or not appreciably outside these limits. The utility of the formula is therefore very limited.

The value of b in each case examined by Mr. Janitzky is given as 175 which would appear to be a constant figure for 0.45 per cent carbon steel under varying conditions of treatment. It is difficult to see, however, how such a uniform figure has been arrived at. Close calculation of the untempered, water quenched, and oil quenched specimens, cases (1) and (4), gives the following figures:

Case No.	Treatment	Value of b	Value of d
1	Water quenched	214.4	0.49
4	Oil quenched	142.9	3.86

There is thus a very considerable difference between the values of b obtained by strict application of the formula, for the same steel. This further demonstrates the empirical nature of the formula, because, if it has a

The author, Sir Robert Hadfield, is chairman Hadfields, Ltd., 22 Carlton House, London Eng. Many of these criticisms are answered in a new paper by Mr. Janitzky, which appears on page 377 of this issue of TRANSACTIONS.

physical significance, it represents in both cases the hardness produced by an exceedingly slow rate of cooling, and the two figures therefore should be identical.

It should be carefully borne in mind that there is often considerable latitude in the selection of empirical formulae to suit a series of physical data. The applicability of Mr. Janitzky's hyperbolic formula, therefore, especially as it contains arbitrary constants, must in no way be regarded as a vindication of the physical hypotheses taken as the starting point.

Mr. Janitzky, however, has done a service in looking into this question, and his calculations will, it may be hoped, lead others to investigate the subject further.

INFLUENCE OF THE HEATING MEDIUM ON THE STRUCTURAL CHANGES IN STEEL

By A. E. Bellis

IN TREATING steel the practical man's object is to change its properties from a soft and ductile metal to a hard and brittle one, or vice versa. The degree of change and the skill with which the desired properties are obtained, measures his skill as a heat treater. In scientific terms, the metallurgist speaks of changing the structure of his steel and he uses all the tools of science to control and identify these changes. In this paper, a more or less scientific analysis is presented of these structural changes as they are influenced by the heating and cooling medium. Special emphasis is to be given to the results as expressed in the shop man's terms of strength, hardness, toughness, brittleness, etc.

The fact that the rate of heating or cooling is the fundamental factor in changing the properties or structure of steel is rarely given the consideration that its significance warrants. It isn't the temperature to which a piece is heated that is of such fundamental importance as it is the rate at which a piece cools from that temperature which determines its structure and properties. Of course, it is necessary to exceed the critical temperatures of the steel, to change the temperature. It is an interesting point to bring out that it has been shown by some recent research work that the critical temperatures that we usually speak of as landmarks vary if the cooling or heating rate is slower or faster. Those critical temperatures which we have thought of as a definite figure are not a definite figure, but they vary with the rate at which the temperature changes, thus the critical point given for a certain analysis steel is not of any value unless the rate of heating and other dependent data are given.

The importance of considering the abstract idea of rate of heating rather than of concrete temperatures is apparent on going over the heat treatment of a carbon steel cutting tool, keeping an eye on the time effect. The tool is heated slowly to, say 1400 degrees Fahr., kept there just long enough to know that it is all at that temperature and then very rapidly cooled down to 750 degrees Fahr. or thereabouts. By the rapid cooling the physical condition reached at the high temperature is to a great extent maintained, with corresponding properties and structure of hardened steel. The steel is now in a very unstable condition and has a strong tendency to change to a more stable form which happens to be softer, the annealed state being the really completely stable form at room temperature. It is out of equilibrium and will "obey that impulse" to change gradually back to the stable state if it is heated. So we draw it. We heat it up to a temperature where it can ease back toward the softer state of comparative equilibrium and keep it at that temperature until it reaches the exact condition we desire.

If the work is slowly heated to a relatively low temperature in tempering, different results are obtained than by heating rapidly even to higher temperatures. The rates of heating and cooling are obviously very important and depend entirely on the surrounding medium of solid liquid or gas. In the open fire or muffle furnace, where the heating

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A paper presented at the Indianapolis Convention. The author, A. E. Bellis, is president, Bellis Heat Treating Co., New Haven, Conn.

medium is a gas, the heat is conducted from the flame rapidly at points of contact or transmitted slowly by radiation through an oxidizing and poorly conducting gas. The heating then is far from uniform, and difficult.

When the work is surrounded by packing material the heating is by conduction through the solid material. In this method the disadvantage of oxidation is eliminated to a great extent but its disadvantages and difficulties are well known. If the medium is a mobile liquid of high specific heat the mechanism of the heat transference between the medium and the work is altogether different. By convection currents the liquid is kept moving past the work and new portions of the bath, at the temperature of the bath, are always in contact with the work. Thus the heat flows uniformly into the work from all directions. The conductivity of the bath material is not a factor as it is negligible alongside of the continual intimate mixing of the liquid. The specific heat, or heat-storing-capacity, obviously is a controlling factor.

Of liquid heating and cooling media the ones most used are, of course, water and oil. It is interesting to note at this point that mercury is not as effective a quench as water. Although its conductivity is high, its specific heat is much smaller than water. In the same way the perfected salt bath is more effective as a quench than the lead bath. We have found that more complete hardening results from quenching in the perfected salt bath at temperatures up to 1350 degrees Fahr. than can be obtained from quenching in lead at 1000 degrees Fahr. This medium is a salt bath which started with a barium bath, but this was discarded about five years ago, 1916 to be exact, and we have been doing research work on it ever since. We have gone a long way from the original point, and our present bath will be mentioned here several times as the "perfected salt bath." This perfected salt bath is not to be confused with the many other salt baths that are on the market and have been tried for a good many years.

On a cold day metals feel cold because they conduct the heat away from your hand quickly in spite of their low specific heats. Stones, although their specific heat is many times as large, conduct the heat away slowly, and hence do not feel as cold. Thus, one might thoughtlessly conclude that a liquid metal would be a more effective quench than a molten stone. However, a little thought shows that this is not so. The quantities of heat concerned in the first instance are so small that the specific heat does not enter into consideration. In the latter case it is of paramount importance, and the formerly important factor, the conductivity, is now negligible, the materials being mobile liquids.

Applying these principles to the hardening of high speed steel, we find it not only possible to quench effectively at a high temperature, as mentioned above, but greatly advantageous. Hardened high speed steel is unstable and has a strong tendency to change into the annealed state. The word stable here in a different manner from which Mr. O'Neil, I believe it was, used it in speaking of high speed steel. It is a technical term used in theoretical chemistry, but I think its meaning will be brought out by the way it is used. If hardened high speed steel is heated, it becomes annealed to a degree depending on the temperature and length of time at that temperature. It has the impulse to change to

that annealed form. We heat it up and it starts changing, and as soon as we have it at the point desired, heating is stopped.

The conventional treatment of a high speed steel tool is to heat it to, say 2300 degrees Fahr., quench it at room temperature, and reheat for a time to 1000 degrees Fahr. or thereabouts. The steel is vigorously jerked out of equilibrium and then allowed to ease back to the point desired. This is like stretching a rubber band to the breaking point and then letting it shorten to the final desired length. The damage, distortion, cracking, etc., is done in the quenching, jerking it so far out of its state of equilibrium and subjecting it to a sudden change of temperature of 2000 degrees or more.

Why do we not put it immediately into the state we want instead of straining the tool by over-shooting? Because, heretofore the only way to get sufficient speed of cooling, or rather the correct speed of cooling, past the critical temperature has been to have the temperature difference between the tool and the cooling medium very great, approximately 2000 degrees. If we could put it into the state we wanted directly, it would be very convenient, and it has been tried a good many times, but it has been found impossible. Experimenters have tried, as Mr. D'Arcambal has said, to quench it at 1100 degrees Fahr. in oil to obtain that effect. They found that it was impossible to get the best results that way because the rates of heating and cooling used were not correct. The exact rate of heating and cooling of any part of the tool is something that it is practically impossible ever to know. You can determine the temperature at any given time, but there is always a lag in the pyrometer. These lags are very great sometimes, and the speed of cooling is great. If it is a little too great or a little too small you do not get the correct effect.

The rate of cooling is dependent upon the temperature difference between the work and the contiguous part of the medium. If the medium does not circulate freely, that part next to the work quickly becomes nearly as hot as the metal, and the temperature difference becomes small. If, however, the medium is a very fluid liquid moving past the piece, the temperature difference between the work and the contiguous part of the bath is practically as great as between the average temperatures of each, and the heat transfer is so facilitated that sufficiently rapid cooling takes place if the specific heat is great enough, in quenching at 1000 degrees Fahr. or higher.

Temperature change of the tool per minute is proportional to the quantity of heat removed per minute, which is in turn proportional to the temperature difference between the tool and the contiguous portion of the bath, provided the bath has sufficient heat absorbing capacity per unit volume.

The efficacy of the quench depends on speedy removal of a quantity of heat, ending up at a temperature only sufficiently low that the tendency to reach equilibrium is controllable. That is to say, we want to get the effect that is usually obtained by quenching in oil and then drawing, and what we want at the end is to have the steel stable at 1000 degrees Fahr. No matter what method is used, you end up at 1100 degrees Fahr., because high speed steel, to be good, must have a chronic structure at that temperature. Distortion is due to the great change in temperature, therefore, what we want is a speedy cooling

only down to the point where danger of overdrawing is past. This can now be accomplished in the perfected salt bath. This method has the additional commercial advantage of eliminating one operation, the draw.

Lead at 1000 degrees Fahr. has been used for quenching high speed steel and found to be not entirely satisfactory. This is because its specific heat is so small that the addition of a little heat from the work raises the temperature of the lead locally to such an extent that the temperature difference between the work and the medium is so reduced as to cut down the rate of cooling to cause hardening uncertain.

This paper has been boiled down to that point, and will be left the way it is, except for one or two facts further. The authors intended to have a large table of statistics, but we hadn't obtained the data at the last minute, and it was necessary to take this rough report, which showed an increase of 20 per cent, consistently, not in speeds or feeds, but in inches of material cut before the material dulled. We have not conducted any tests pieces to speak of, and we have not used the Brinell or scleroscope instruments a great deal. All the results are based on the work that the tool does before it gets dull, the speed at which it will work and the amount of material that it will cut. That is the final objective, and that is what we have been working for directly without taking any middle steps. The whole object has been to get this red hardness, this tool which will work at 1100 degrees Fahr. and do the work and do more work than has been done before.

Also the rate of cooling from the salt bath in the water, for instance, on carbon steel is controlled by the film of salt which stays on the tool. When it is taken out of the salt bath, it has a slight film of salt on it. There are possibly several thousand analyses of salt baths. If you get exactly the right one, you have a peculiar film on the tool that has the peculiarity that when it is put in the water, the speed of cooling will be controlled, so that you will obtain the hardness without over-straining the tool.

Discussion of Mr. Bellis' Paper

MR. D'ARCAMBAL: You say you gained 20 per cent over what? In cutting tests?

MR. BELLIS: That 20 per cent, I haven't the figures of speeds and feeds, was in the inches of material cut before the tool needed regrinding.

MR. D'ARCAMBAL: What do you mean?

MR. BELLIS: Twenty per cent increase in the number of inches the tool will cut.

MR. SAWTER: Do you mean to say that your molten salt bath will conduct heat away quicker than hot lead will?

MR. BELLIS: Much quicker.

MR. SAWTER: How much quicker?

MR. BELLIS: Well, of course it is hard to say how much quicker without figuring it out. On two particular pieces you could try that. It would depend on the size of the piece and the temperature. You know that the specific heat of lead is about one-tenth that of the salt bath. It is about one-tenth of almost any salt bath. The specific heat of the salt bath is 0.20 or 0.30, and the specific heat of lead is 0.03, and the density of the lead, of course, is five times as great. That is in favor of lead. But the salt bath has a specific heat ten times as great, and one-fifth as much specific gravity; its heat capacity per unit vol-

ume is just twice as great as lead. Therefore, if you take any one moment during the cooling, there is some of the salt immediately against the piece, and the heat flows from the piece into the salt. In so flowing it raises the temperature of the salt. Now if the specific heat is twice as great, it will raise that temperature just one-half as fast and the faster that rises, the slower it will cool.

MR. SAWTER: What about your conduction?

MR. BELLIS: It is conduction just at that point, but conduction through the bath doesn't have any appreciable affect, because the bath is continually mixing.

MR. SAWTER: Also I would like to ask the question as to the comparison of the cost of maintenance over gas fired and oil fired.

MR. BELLIS: I couldn't give you exact figures on the cost of maintenance, but the last figures that I saw that would be at all comparable to that were prices on chaser dies, threading machine dies. A cost account was kept for those and we found that in treating them in the salt, of course—by the way, the results were a great deal better because of the lack of distortion, etc.,—the cost of treating them in the salts was less than it was the other way, but it was principally, I believe, due to the fact that it was done a great deal quicker. They would have the salt baths in a row; for instance, in the high speed work we have the pre-heat, the high heat and the quench and the dies are moved at two or three-minute intervals, according to the size of the piece, from one bath to the next. It is a continuous operation, and the time is reduced to such an extent the cost of heat treating the die is much less than it would otherwise be.

MR. D'ARCAMBAL: Taylor, in his experiments 20 years ago found that the rate of cooling after heating to the quenching temperature made absolutely no difference to it. The whole thing depended on the quenching temperature. We have tried to verify that, as far as hardness goes. We took two pieces from the same bar of steel, one we buried in lime after heating to 2350 degrees Fahr. and the other we quenched in ice water, and both were file hard and had exactly the same microstructure.

MR. BELLIS: The only time I can think of that being true is in the old Mushet steel. Every one knows that if high speed steel is cooled slowly enough, it will not be hard.

MR. D'ARCAMBAL: We threw a piece in lime and let it cool.

MR. BELLIS: If you let it cool and take 24 hours to get down it will be annealed.

MR. D'ARCAMBAL: I don't agree with you on the rate of cooling.

MR. BELLIS: If high speed steel is heated to 2300 degrees Fahr. and cooled slowly enough, it will be annealed when it is cooled. If you cool it quickly, it will be hard.

MR. D'ARCAMBAL: I am comparing a one-minute cooling with about an hour's cooling.

MR. BELLIS: It is just a case of taking it to the extreme to show the rate does have an effect. That is my point.

CHAIRMAN FOLEY: I think Mr. D'Arcambal's idea is that it remains austenitic. If you reduce it very rapidly or very closely, it still remains austenitic.

MR. BELLIS: My point is that we wanted to produce the method that gives results and we have now done it.

CYANAMIDE IN LIQUID CASE HARDENING

By P. W. Shimer and E. B. Shimer

USE of calcium cyanamide for case hardening, by reason of its high carbon and nitrogen content, suggests itself very naturally to the metallurgical chemist. Its use for this purpose, therefore, dates back at least 16 years, when a patent was granted to Gustav Deininger, of Berlin, Germany, for its use in a pack hardening mixture.

When in 1915, because of the scarcity and extremely high price of sodium cyanide, the authors began experiments with commercial cyanamid in liquid case hardening, it was soon found that, on account of the interminable frothing caused by its addition to mixtures of fused salts, and because of the thickening and clogging up of the melt by reason of the residual material left in it, its use was impracticable in this form. After a good deal of experimenting in the laboratory the idea was conceived of combining the powdered cyanamid in proper proportions with a hard pulverized pitch and coking the mixture at a high temperature. (U. S. Patent No. 1279458). In the laboratory use of this coked mass, in lump form, in various mixtures of salts having suitable melting points, the frothing and other troubles were overcome. In its first commercial application, the Ingersoll-Rand Co., of Phillipsburg, N. J., coked in their furnaces the mixtures of cyanamid and pitch prepared in our laboratory and used it successfully with the mixture of salts through the emergency caused by the very high cost of sodium cyanide during the war. In further laboratory researches and experiments it was found if we used hard, well converted calcium cyanamide, canned and sealed as fresh as possible from the furnace in which it was made, that we could use this in lump form to replace our coke with important advantages. (U. S. Patent No. 1279457).

While these two processes were first developed in all their essential details in the authors' private laboratories and furnaces, the first use in a commercial way was by the Ingersoll-Rand Co.; and they have used it continuously and successfully for over five years. We desire to acknowledge our indebtedness to John Halbing, superintendent of the heat treating department of that company and his assistants, for their co-operation in this work. Efforts to introduce the process to more general use were undertaken comparatively recently and only in a conservative manner. The first publication was made in a paper on "The Shimer Case Hardening Process", read by Dr. Joseph W. Richards, professor of metallurgy, Lehigh University, before the American Institute of Mining and Metallurgical Engineers in February, 1919.

In this process two materials are used:

1.—The special lump calcium cyanamide to which has been given a registered trade name. It has a high content of carbon and nitrogen, both of which elements are essential in liquid case hardening. It is a hard, infusible, rock-like material, black in color and lighter than the melt in which it is used. When perfectly protected from atmospheric moisture, it remains hard for an indefinite time; a sealed can of it recently opened was hard and unaffected after over two years storage. When exposed to air, however, it gradually softens and finally falls to powder,

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acting in all respects like air-slacked lime. It is of first importance, therefore, to protect this material as far as possible from atmospheric moisture, for if it becomes soft, it disintegrates in the melt, causing frothing and a heavy scum on the surface.

2.—The easily fusible mixture of salts, with no case hardening properties, given a registered trade name, is a mixture in proper proportions of pure dry calcium chloride and sodium chloride of suitable purity and physical properties. In laboratory tests, other mixtures have been used successfully but, for the present, at least, the mixture now used is probably the best for general purposes. Among its advantages are that it is cheap and that it permits the use of the higher temperatures with but little loss by volatilization. It has a melting point of about 1150 degrees Fahr. The material is, however, hygroscopic and must be kept well covered to prevent the taking up of air-moisture. With a little care to keep containers covered, there will be no trouble with these materials.

In carrying out the process, the same furnaces and pots employed in cyanide hardening, generally, may be used. The only additional equipment necessary is a perforated metal basket for holding the cyanamide and sinking it to the bottom of the melt. The amount of the material commonly used to impart case hardening properties to the inert fusible salt bath is 5 per cent of the weight of bath needed to fill the pot to the required depth. The basket is easily made of perforated metal, with perforations about ¼-inch in diameter, and of a shape conforming to the shape of the bottom of the pot, but with sufficient play all around so as to insure easy removal. The baskets should be only high enough to hold the necessary amount of cyanamide so as not to lessen too much the available depth of the pot. The basket must be provided with an easily removable perforated cover which must be well fastened down, otherwise the cyanamide will float out. When such a basket of proper size and shape is used, the case hardening combinations are formed over the whole bottom of the pot, from which the generated gases convey them uniformly up and throughout the melt. The size of the cyanamide, pieces varies with the size of the pot, but in all cases, they should be freed from powder and soft material, for these may cause frothing. The melt penetrates the hard cyanamide very slowly and it is often advantageous, after a day's run, to break the larger pieces into two or three smaller ones. This exposes fresh surfaces and another days run often may be secured from this broken material. When breaking up cyanamide by hand, it is well to use gloves, for the powder is irritating to chapped or abraded skin. The manufacturers of the material protect the hands of their workmen by use of vaseline. The activity of the bath is directly proportional to the surface exposed. Since the smaller pieces expose several times as much surface in proportion to their weight as the larger ones, it is sometimes well to take advantage of this when extra quick action is desired, or when toward the end of a day's run, it is desired to boost the strength quickly. This may be accomplished by use of smaller baskets filled with coarse granules of the material, which may be let into the melt on top of the large basket at the bottom. Commonly the size of cyanamide used in the large basket varies from ¼ to 2 inches in diameter.

Since in this process, as well as in the cyanide process, the oxidizing action of the air on the surface of the melt is destructive to the case

hardening compounds, it is well to keep the pot covered closely when not actually in use. For this reason the black scum which sometimes comes to the surface of the melt is not without certain advantages, for it protects the melt from the air and, when used at the higher temperatures, lessens loss by volatilization. It also lessens radiation of heat from the surface of the melt and to that extent saves fuel.

It may be added here that in the laboratory experiments, it was found that, when the 5 per cent of cyanamide, instead of being added at one time and in coarse pieces, is added at intervals in five wire-enclosed charges, containing each 1 per cent of the weight of the melt of coarse granules, there is a marked economy and maximum case hardening results per unit of material are secured. When, in these experiments, the melt was covered so as to protect it from the oxidizing action of the air, there was still further marked economy.

Before lowering the basket of cyanamide into the melt it must, of course, be hot and dry to prevent sputtering out of particles of the melt. This is especially true when material from the preceding day's melt adheres to the basket. It must then be thoroughly preheated either on the furnace or in a preheating furnace, if one is conveniently at hand. This drying of the basket may be simplified if the precaution is taken to place it in a suitable can or other receptacle provided with a tight cover as soon as possible after removal from the bath.

Immediately after the basket is lowered into the pot the bath begins to show activity and after a short time there is a rapid evolution of gases upon the surface, which at the height of activity, covers the top with numerous small yellow flames. The strength of the bath may be judged from the activity of this evolution of gases upon the surface. As the case hardening strength dies down, the bath becomes more quiet. Until quite familiar with the appearance of the bath, it is well to test its case hardening strength by testing it upon a nail at intervals.

The temperatures commonly employed vary from 1425 to 1700 degrees Fahr., usually about 1450 degrees Fahr. The deeper cases, up to 1/32-inch, are obtained in from 1½ to 2 hours at the higher temperatures. After quenching, the steel must be treated with a hot solution of soda ash. This is important, for the trace of calcium chloride which remains on the steel after quenching facilitates rusting. The hot soda ash solution decomposes this trace of calcium chloride and converts it into harmless calcium carbonate. Another advantage of this treatment is that the steel on removal from the hot solution dries rapidly.

When the basket of cyanamide is nearly exhausted, it is lifted out of the melt and replaced by a fresh basket. When the basket is provided with an easily replaceable cover, the material may be dumped out immediately after removal from the pot and fresh cyanamide may be filled into the hot basket. On examination of the spent cyanamide the pieces will be found to have preserved their original size and shape. The fusible salt bath has simply removed from them their case hardening elements, thereby leaving the inert residue. Of course, new bath mixture must be added from time to time to keep up the level of the pot and to replace that which is carried out by adhering to the work. On account of the thinly liquid character of the bath at the case hardening temperatures, this loss is reduced to a minimum. Upon quenching, this thin film flies off instantly, leaving the work with a clean surface.

To determine the nature of the gases given off from the active melt,

they were collected under a bell-shaped iron casting, the rim of which was immersed in the melt. From this bell they were led off and collected in large two-gallon bottles for chemical analysis. This operation was repeated so that a comparison could be made of the gases given off on different days and under slightly different conditions. The results follow:

Test No.	Nitrogen per cent	Carbon monoxide per cent	Carbon dioxide per cent
1	69.5	26.0	4.5
2	80.8	19.0	0.2

A careful cyanogen test was made on a sample of six liters of the gas, but no trace of it could be found. This result is confirmed by the fact that there is absolutely no odor, or any gas of an irritating character, given off from the melt. The carbon monoxide burns on the surface of the pot and the only gases finally given off into the shop are harmless nitrogen and carbon dioxide. This absolute freedom from every trace of poisonous and irritating gas is a great source of safety and comfort to the workmen.

It would be interesting to know all the chemical reactions which go on in the melt and a good deal of work has been done to determine them. As a result we have some pretty well defined ideas of what goes on when the fusible salt bath and cyanamide react at high temperatures and when in turn the resultant compounds react with the oxygen of the air. However, we feel sure that the remarkable case hardening activity of the bath is due in part, at least, to the fact that the case hardening elements are in a nascent state and are therefore peculiarily active. In the same bath and at the same time in which the compounds are interacting to form case hardening combinations, the steel is present to take up the nascently active carbon and nitrogen.

To get comparative results between cyanamide and sodium cyanide, the following experiments were made in a small gas-fired furnace in the laboratory, using a deep pressed steel pot holding 20 pounds of melt. The steel used was a simple steel and the pieces were 1-inch in diameter and 5 inches long. The turnings made in turning down the pieces were preserved and part of them were case hardened along with the steel pieces.

Experiment 1.—Twenty pounds of bath mixture were melted down and a perforated cast-iron basket containing one pound of cyanamide in small pieces was sunk to the bottom of the pot. When the temperature had reached 1526 degrees Fahr. the piece of steel and the wire basket of turnings were immersed in the melt and left there for one hour at that temperature. The piece of steel was then removed and annealed by allowing it to cool at the bottom of the ladle full of the melt in which it was removed from the pot. This also allowed the cooling to take place with absolute exclusion of air. The turnings were quenched in water and thoroughly cleaned and carefully dried for analysis. During the whole hour of the experiment the pot was kept covered as closely as possible.

Experiment 2.—This experiment was a continuation of Experiment 1, the only difference being that the pot was uncovered during the hour of its duration. The same temperature, 1526 degrees Fahr. was maintained and the second steel piece and turnings were similarly treated.

Experiment 3.—A clean steel pot of the same dimensions as in the

first two experiments was used; the pot had been used before for case hardening. It was filled with pure sodium cyanide without other admixture, and the time and temperature were the same as in the first two experiments. The third piece of steel, and turnings also, were treated exactly as before. As in Experiment 1 the pot was closely covered during the whole hour.

Experiment 4.—This was a continuation of Experiment 3, the only difference being the removal of the cover from the pot. The fourth piece of steel and turnings were treated as before for one hour.

The steel used had the following composition:

	Per cent
Carbon	0.092
Silicon	0.185
Sulphur	0.036
Phosphorus	0.012
Manganese	0.402

The turnings after case hardening as above contained carbon as follows:

Experiment No.	Treatment	Per cent
1	Cyanamide covered	1.39
2	Cyanamide uncovered	0.806
3	Cyanide covered	0.796
4	Cyanide uncovered	0.712

The case hardened pieces were turned up in such a way that we got an approximate first cut of 1/200 inch, a second cut of 1/100 inch and a third cut of 1/100 inch in each of the four experiments. Careful determinations of carbon and nitrogen were made in each set of turnings. As an extra precaution against incomplete combustion and other possible errors, the carbon determinations were made by the standard method of solution and combustion.

The carbon and nitrogen results are as follows:

Cut No.	Depth of cut inch	Carbon per cent	Nitrogen per cent
Experiment 1, Cyanamide Covered			
1	1/200	0.754	0.301
2	1/100	0.254	0.041
3	1/100	0.160	0.039
Experiment 2, Cyanamide Uncovered			
1	1/200	0.576	0.220
2	1/100	0.472	0.140
3	1/100	0.188	0.024
Experiment 3, Cyanide Covered			
1	1/200	0.622	0.351
2	1/100	0.268	0.081
3	1/100	0.108	0.028
Experiment 4, Cyanide Uncovered			
1	1/200	0.528	0.240
2	1/100	0.180	0.060
3	1/100	0.128	0.028

Prof. Henry Fay, of the Massachusetts Institute of Technology, finds that nitrogen is present in all case hardened steel, especially steel treated by the liquid melt processes. He finds also that at the higher temperatures, the amount of nitrogen taken up is considerably less than at ordinary case hardening temperatures. In this process we, as well as other investigators, have found consistently higher carbons and lower nitrogens than in the cyanide process, time and temperatures being the same.

An application of the process which is being made with success is its

use as a heating bath in place of lead for certain classes of work. The advantages of a heating bath of fused salts are several: 1. Its low specific gravity as compared with lead allows the work to be suspended freely in it; 2, the slower heating lessens distortion of pieces of intricate design and with heavy and thin sections of metal; 3, the work comes out of the water quench clean and bright. From the lead bath the work often comes covered in spots with lead and dross which is hard to remove, especially from threaded parts. The parts under the adhering lead also remain soft, after quenching. A disadvantage, however, of a heating bath of fused salts, is that the baths have a slight decarburizing action on the steel. This we have overcome simply by introducing into the bath a small basket holding not more than 1 per cent of the weight of the melt of cyanamide. Or, if cyanamide case hardening is going on near by, an occasional small ladle of the case hardening bath added to the heating bath will answer the same purpose. By this procedure just enough carburizing activity is imparted to the heating bath to counteract the decarburizing action and not enough to cause case hardening to any undesired extent.

When an oil quench is used on steel heated in a heating bath of salts, the work is more difficult to clean than work quenched from a lead bath; on water quenched work the advantage in cleaning is with the salt heating bath. We may add, at this point, that the fusible salt bath may be used to great advantage as a fusible cover for lead pots in place of charcoal. Enough of it is placed on the well cleaned lead to cover it to a depth of about ½ inch. This works admirably for water quenched work; oil quenched work is difficult to clean and for such work it is better to use the usual covering of charcoal. Whenever the bath mixture is used, whether in a case hardening bath, heating bath, or lead pot cover, it is necessary to give the work a final treatment in a hot solution of soda ash.

On the subject of cyanamide case hardening we may add that we consider that its worth as a case hardener is well proven by five years of successful use on a wide variety of work. All that is necessary is for the user to become familiar with a few simple details and points in which the process differs from the cyanide process. When these are attended to it will be found that the case obtained is fully as hard and deep as can be obtained by any other liquid process, while the advantages are a materially lower cost and an absolute freedom from poisonous and irritating gases, with consequent comfort and safety of all who must work in the shop in which the case hardening is done.

TENSILE PROPERTIES OF SOME STRUCTURAL ALLOY STEELS AT HIGH TEMPERATURES

By H. J. French

IN THE attempted production of ammonia in the United States by the Haber process[1] gradual elongation and ultimately fracture of bolts in converter chamber heads has introduced serious operating difficulties. Under a mean temperature of 550 degrees Cent. to which heads, nuts and bolts were subjected the elongation of the latter was such as to require tightening of the nuts almost daily. The use of some of the more commonly employed structural alloy steels did not remove this difficulty and a search of the literature revealed little exact information on which a comparison of the high temperature tensile properties of various alloy steels could be based.

In view of the fact that an investigation of the resistance to corrosion by ammonia of various ferrous and nonferrous alloys was in progress in connection with redesign of operating equipment by the ordnance department, the Bureau of Standards was requested to undertake determination of the tensile properties of a number of structural alloy steels throughout the temperature range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) From the combined results of investigation of resistance to corrosion of various metals and the tensile properties of steels at high temperatures, it was hoped that selection of a suitable alloy for withstanding required stresses could be made and if this proved unsatisfactory as regards resistance to attack by the gases encountered at least a more suitable metal lining for the converters could be installed.

The original plan of procedure included tests of a plain carbon steel and a number of structural alloy steels most of which were of acknowledged industrial importance. However, because of the desire to keep variations in carbon content to a minimum, difficulty was encountered in obtaining some of the alloys, notably carbon-manganese and chromium-molybdenum steels, of the exact compositions desired so that this report comprises only tests of four steels.

It is further restricted to tests of these alloys in a normalized condition as data so obtained form a basis of comparison with tests of samples first subjected to quenching and tempering. The high operating temperatures attained, which reach about 650 degrees Cent. (1200 degrees Fahr.) limit the tempering subsequent to hardening to relatively high temperatures while the large dimensions of the converter heads and some of the other parts of the equipment subjected to high temperatures, which would introduce difficulties in quenching, make the use of a forged or normalized steel highly desirable.

Shortly after completion of the tests about to be described, tensile properties at high temperatures of a number of carbon and alloy steels subjected to varying thermal treatments were reported by MacPherran[2] and in discussion of this paper by Spooner considerable additional data were presented. However, the work of MacPherran and Spooner was confined, in so far as the elastic properties are concerned, to determina-

1. R. S. Tour: "The Direct Synthetic Ammonia Process," Journ. Ind. and Eng. Chemistry, 12, No. 9, September, 1920, p. 844.
2. R. S. MacPherran: "Comparative Tests of Steels at High Temperatures," Proc. Amer. Soc. for Test. Mats., 1921.

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tion of yield point whereas the tests carried out by the present author include determinations of the limit of proportionality, and strength at fracture and the interpretation of these data is somewhat different from that given by either of the authors mentioned.

As already indicated, there was until quite recently a scarcity of accurate data on the high temperature tensile properties of various structural alloy steels. This is still the case as regards the effect of temperature on the limit of proportionality, of importance in design of engineering equipment, and in addition there is some disagreement between results reported by different investigators for similar alloys. Bregowsky and Spring[3] determined yield point, tensile strength, elongation and reduction of area from 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) for rolled 30 per cent nickel steel.

In 1913 Schulz[4] reviewed available data relating to the high tem-

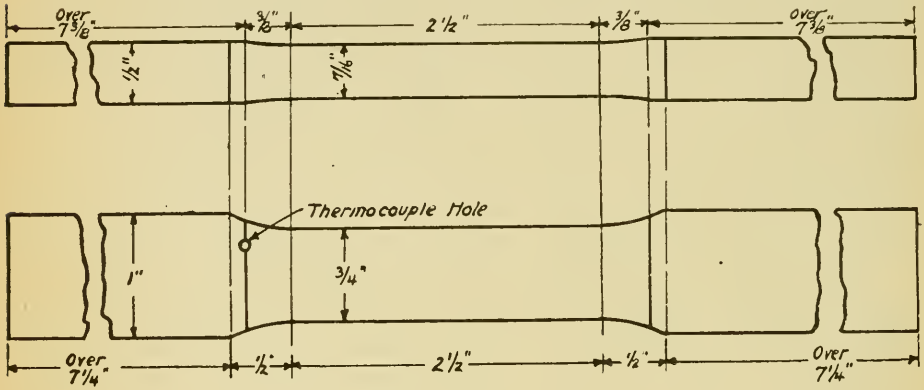

Fig. 1—Form and dimensions of test specimen used

perature properties of turbine materials but the information presented for alloy steels was in large part for those containing varying proportions of nickel.

Guillet[5] reported, among several special alloys for use at high temperatures, a steel containing nickel, chromium and tungsten which showed exceptionally high strength at 750 to 800 degrees Cent. (1380 to 1470 degrees Fahr.)

A comprehensive analysis of the effects of high temperatures on hardness, tensile and impact properties, freedom from warpage, etc., of steels containing 3 per cent nickel and various proportions of chromium, high speed steels and various chromium and chromium-cobalt steels was recently prepared by Gabriel[6]. As regards high tensile strength at elevated temperatures these steels were considered of value in the following order:

1. High tungsten

3. I. M. Bregowsky and L. W. Spring: "The Effect of High Temperature on the Physical Properties of Some Alloys, Proc. Inst. Assoc. for Test. Mats., VI Congress, 1912, VIII.

4. Schulz: "Neuere Versuche und Erfahringen mit Turbinenschau felmaterial fur hohe Temperaturen," Die Turbine, 9 (1913), p. 243.

5. L. Guillet: "Alloys Having Remarkable Properties at Very High or Very Low Temperatures," Rev. Met. 11 (1914), p. 969.

6. G. Gabriel: "Comparative Values of Motor Valve Steels." Iron Age, 106 (1920), p. 1465.

2. High chromium, high carbon
3. High chromium, low carbon
4. 3 per cent nickel and nickel-chromium.

In the selection of steels for valves the author recommended the different type alloys as follows:

1. A tungsten steel

Table I

Alloy Steels Tested at High Temperatures

By Mac Pherran*

Type composition, per cent					
Carbon	Manganese	Nickel	Chromium	Vanadium	Condition in which steel was tested
0.21	....	3.25	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.25	....	33.9	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.34	....	2.38	0.38	....	816 degrees Cent. (1500 degrees Fahr.) water. 705 degrees Cent. (1300 degrees Fahr.)
0.53	....	20.78	7.42	....	As rolled.
0.30	....	....	0.83	0.17	857 degrees Cent. (1575 degrees Fahr.) water. 732 degrees Cent. (1350 degrees Fahr.)
0.69	....	....	3.36	....	843 degrees Cent. (1550 degrees Fahr.) water. 705 degrees Cent. (1300 degrees Fahr.)
0.72	0.92	....	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.82	....	....	0.91	0.18	816 degrees Cent. (1500 degrees Fahr.) water. 705 degrees Cent. (1500 degrees Fahr.)

*American Society for Testing Materials, 1921.

Table II

Alloy Steels Tested at High Temperatures

By A. P. Spooner*

Type composition, per cent						
Carbon	Nickel	Chromium	Vanadium	Molybdenum	Tungsten	Condition in which steel was tested
0.10	....	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.45	....	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.33	3.5	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.38	2.0	1.0	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.37	....	1.0	0.20	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.47	....	1.0	....	0.35	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
1.10	....	0.50	0.20	....	....	Annealed 740 degrees Cent. (1360 degrees Fahr.)
0.48	....	1.3	0.20	....	....	Annealed 730 degrees Cent. (1350 degrees Fahr.)
0.25	....	14.0	....	....	....	Annealed 790 degrees Cent. (1450 degrees Fahr.)
0.66	....	3.2	0.70	....	15.9	Annealed 905 degrees Cent. (1660 degrees Fahr.)
0.20	....	31.0	....	....	....	Annealed 760 degrees Cent. (1400 degrees Fahr.)

*Proceedings American Society for Testing Materials, 1921.

Table III

Composition and Heat Treatment of Steels Tested

	Composition, per cent								Heat treatment*
Steel	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Vanadium	Degrees Cent.
A	0.38	0.56	0.014	0.013	0.14	....	....	....	850
B	0.37	0.67	0.021	0.010	0.20	3.43	....	....	800
C	0.39	0.59	0.019	0.009	0.23	3.05	0.93	....	850
D	0.37	0.74	0.020	0.023	0.21	....	1.04	0.17	850

*Specimens heated for 30 minutes at temperature designated and cooled in still air.

2. A steel high in chromium
3. A nickel steel.

MacPherran[7] recently reported tensile tests from 20 to about 650 degrees Cent. (70 to 1200 degrees Fahr.) for a variety of alloy steels under different heat treatments as shown in Table I. In discussion of this paper, A. P. Spooner presented a large number of tests at temperatures up to about 870 degrees Cent. (1600 degrees Fahr.) for the different steels listed in Table II and in general confirmed the work of MacPher-

7. See note 2.

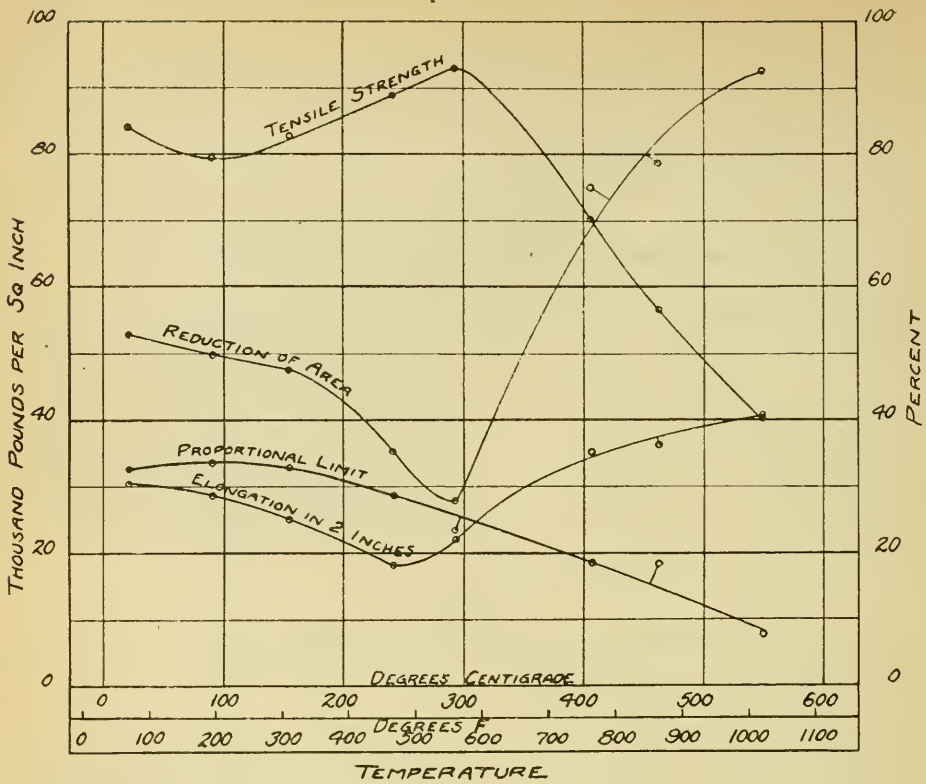

Fig. 2—Tensile properties of 0.38 per cent carbon steel at elevated temperatures

ran in most cases where direct comparisons between results were made possible.

These data, while the most recently presented, are together the most comprehensive compilation of tests so far recorded for the modern types of structural alloy steels but consist of determinations of tensile strength, elongation, reduction of area and, in part of the temperature ranges given, values for yield point.

The four steels tested were made by the electric furnace process at the plant of the Halcomb Steel Co., Syracuse, N. Y., and supplied in the form of 1 by ½-inch hot rolled bars of the compositions shown in Table III. After cutting into desired lengths for test specimens, the bars were normalized by heating to 800 or 850 degrees Cent. and cooled in still air. They were then machined to the form and dimensions shown in Fig. 1.

All tests were made with the special apparatus devised by the author and in the manner previously described[8] in detail.

The results of tensile tests at various temperatures throughout the range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) are given in Tables IV, V, VI and VII and represented graphically in Figs. 2 to 5 inclusive.

Maximum strength of the carbon, 3.5 per cent nickel and nickel-

8. Forthcoming Bureau Technologic Paper "Effect of Temperature Deformation and Rate of Loading on the Tensile Properties of Low Carbon Steel Below the Thermal Critical Range." Also H. J. French, "Tensile Properties of Boiler Plate at Elevated Temperatures," Mining and Metallurgy, 158 (1920), Section 15.

chromium steels occurs between about 240 and 300 degrees Cent. (465 and 565 degrees Fahr.) whereas the strength of the chromium-vanadium steel does not exceed its room temperature value within the temperature range under consideration. However, a rapid decrease in this factor is observed in all steels above about 300 degrees Cent. (565 degrees Fahr.)

At 550 degrees Cent. (1020 degrees Fahr.) the strength of the chromium-vanadium steel is very much greater than that of the other alloys and more than twice that of the carbon steel. It has likewise decreased the least in strength from its room temperature value as shown in Table VIII. However, at all temperatures below about 475 degrees Cent. (885 degrees Fahr.) the strength of the nickel chromium steel is greater than that of the chromium-vanadium.

The proportional limits of the carbon, 3.5 per cent nickel and nickel-chromium steels increase with first rise in temperature and reach maximum values in the neighborhood of 150 degrees Cent. (300 degrees Fahr.) whereas that of the chromium-vanadium steel is greatest at room temperature and, following a marked decrease, again increases perceptibly between about 150 to 250 degrees Cent. (300 to 480 degrees Fahr.) before final decrease occurs. While the maximum value of the limit of propor-

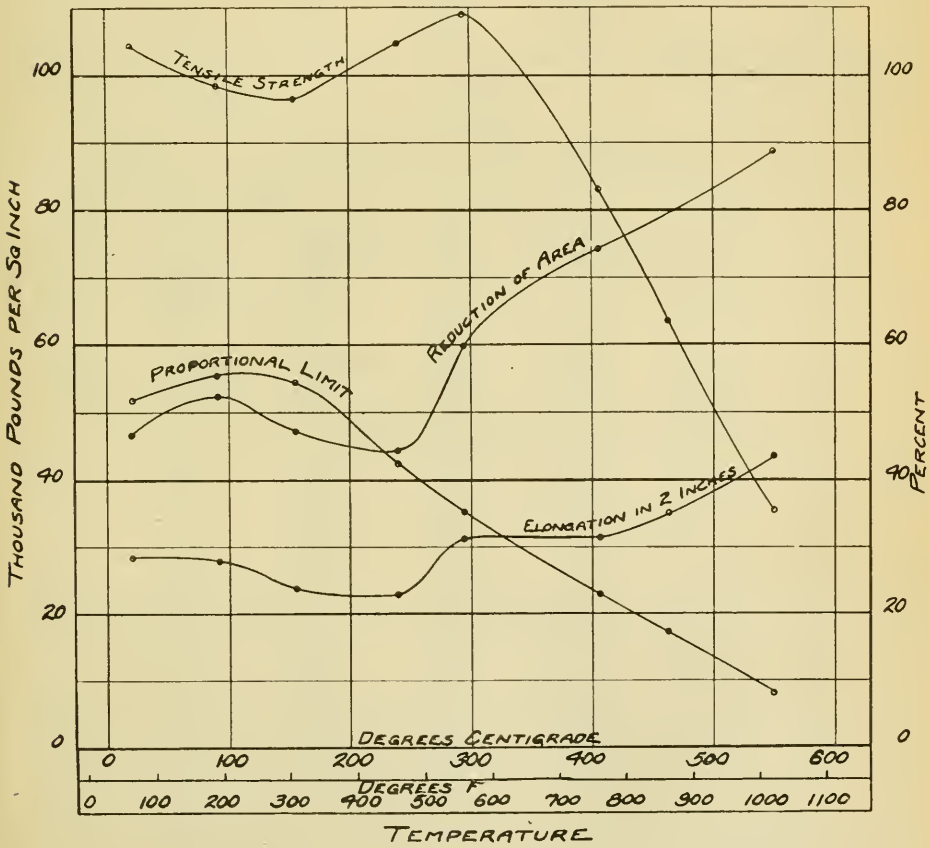

Fig. 3—Tensile properties at elevated temperatures of 3.5 per cent nickel steel containing 0.37 per cent carbon

Table IV

Tensile Properties of 0.38 Per Cent Carbon Steel at High Temperatures

	Chemical composition, per cent		Carbon 0.38	Manganese 0.56	Phosphorus 0.014	Sulphur 0.013	Silicon 0.14
	Temperature of test		Proportional limit,	Tensile strength,	Breaking strength*,		
No.	Degrees Cent.	Degrees Fahr	Pounds per square inch	Pounds per square inch	Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
A-1	Room		34,900	85,200	.....	27.5	52.3
A-2	Temperature		30,500	83,200	.....	33.5	53.3
Av.	21	70	32,700	84,200	.....	30.5	52.8
A-6	92	...	34,000	79,400	.....	28.0	47.6
A-9	92	...	33,700	79,500	.....	29.5	52.2
Av.	92	198	33,850	79,450	.....	28.8	49.9
A-10	155	...	33,250	85,500	140,000	24.5	47.2
A-13	155	...	32,750	80,200	137,000	26.0	48.3
Av.	155	311	33,000	82,850	138,500	25.2	47.8
A-12	241	...	27,500	87,500	129,000	19.0	37.0
A-17	241	...	.....	90,400	127,400	18.0	32.7
A-18	241	...	30,000	88,900	129,700	17.5	36.9
Av.	241	466	28,750	88,950	128,700	18.2	35.5
A-8	292	...	26,000	91,500	.....	24.0	28.6
A-11	294	...	24,500	93,500	116,700	20.0	27.5
A-19	294	...	20,000	94,000	.....	....	....
Av.	293	559	23,500	93,000	.....	22.0	28.0
A-7	407	...	18,500	68,000	137,700	36.5	76.2
A-15	407	...	18,500	72,500	145,800	34.0	73.8
Av.	407	765	18,500	70,250	141,750	35.2	75.0
A-3*	463	...	21,400	57,300	.....	35.5	78.1
A-16	463	...	15,300	56,000	123,700	37.0	79.2
Av.	463	865	18,350	56,650	.....	36.2	78.6
A-21	550	...	9,500	41,700	133,200	38.0	93.0
A-22	550	...	6,000	38,150	109,300	43.0	92.5
Av.	550	1022	7,750	39,950	116,750	40.5	92.7

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

Table V

Tensile Properties at Elevated Temperatures of 3.5 Per Cent Nickel Steel Containing 0.37 Per Cent Carbon

	Chemical composition, per cent		Carbon 0.37	Manganese 0.67	Phosphorus 0.021	Sulphur 0.010	Silicon 0.20	Nickel 3.43
	Temperature of test		Proportional limit,	Tensile strength,	Breaking strength*,			
No.	Degrees Cent.	Degrees Fahr	Pounds per square inch	Pounds per square inch	Pounds per square inch		Elongation in 2 inches Per cent	Reduction of area Per cent
B-16	...	...	47,000	105,150	172,500		30.5	50.6
B-17	Room		56,000	104,900	164,000		27.5	46.7
B-2	Temperature		.....	103,600	152,000		27.5	39.9
B-4	...	...	52,500	103,400	170,800		28.0	49.7
Av.	21	70	51,850	104,250	164,800		28.4	46.7
B-21	92	...	53,000	97,600	169,200		28.5	54.1
B-22	92	...	58,000	97,800	170,300		29.0	52.3
B-1	92	...	.....	99,600	169,500		26.0	51.3
B-3	92	...	.....	99,300	172,300		28.0	52.4
Av.	92	198	55,500	98,600	170,300		27.9	52.5
B-6	155	...	52,500	97,100	170,800		22.0	43.2
B-12	155	...	56,000	96,200	159,700		24.5	47.3
B-19	155	...	55,000	98,300	169,300		25.0	49.4
B-5	155	...	.....	95,000	161,300		23.5	48.5
Av.	155	311	54,500	96,650	165,300		23.8	47.1
B-18	241	...	42,500	104,600	181,200		25.0	51.5
B-7	241	...	.....	106,200	163,600		22.0	40.6
B-8	241	...	42,500	103,500	154,300		21.5	40.9
Av.	241	466	42,500	104,750	166,350		22.8	44.3
B-10	294	...	34,000	109,500	194,400		31.0	60.2
B-9	294	...	36,500	108,900	194,800		32.0	59.7
Av.	294	561	35,250	109,200	194,600		31.5	60.5
B-15	407	...	21,500	83,000	152,600		31.5	74.4
B-13	407	...	24,000	83,250	169,700		31.5	74.5
Av.	407	765	22,750	83,150	161,150		31.5	74.5
B-14	463	...	16,000	63,900	126,400		35.0	79.6
B-11	463	...	18,500	63,500	127,900		35.0	79.7
Av.	463	865	17,250	63,700	127,150		35.0	79.7
B-24	550	...	7,500	37,400	79,000		42.5	88.3
B-25	550	...	9,000	33,300	76,300		44.5	89.5
Av.	550	1022	8,250	35,350	77,650		43.5	88.9

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

tionality of the nickel-chromium steel occurs at about 150 degrees Cent. (300 degrees Fahr.) and is followed by a material decrease, a second rise in value is observed at about 300 degrees Cent. (570 degrees Fahr.) so that this factor is maintained above its room temperature value until temperatures above about 370 degrees Cent. (700 degrees Fahr.) are reached.

The limit of proportionality of the chromium-vanadium steel at 550 degrees Cent. (1020 degrees Fahr.) has decreased proportionally more

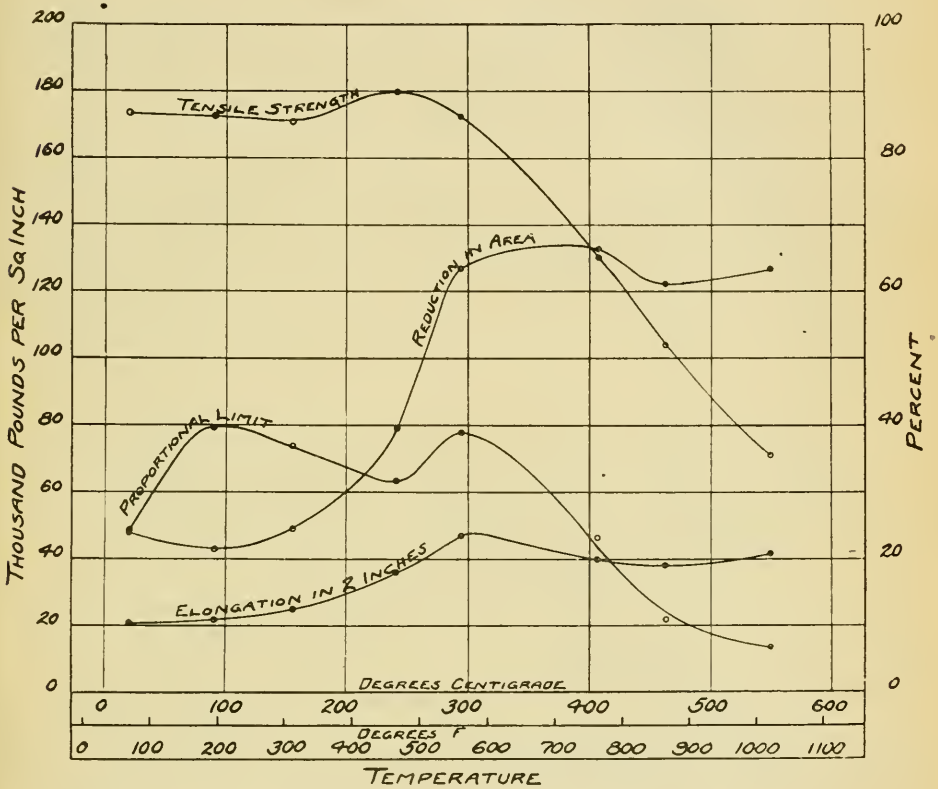

Fig. 4—Tensile properties at elevated temperatures of nickel-chromium steel of the type 3 per cent nickel, 1 per cent chromium and 0.4 per cent carbon

than either the carbon or nickel-chromium steels as shown in Table IX, but its value at the high temperature indicated is greater than either of the latter and more than twice that of the carbon steel.

The effect of temperature is greater upon the values of reduction of area than elongation. In general the inflections in the temperature-elongation and temperature-reduction of area curves shown in Figs. 2, 3, 4 and 5 are so varied that no attempt will be made to describe them. However, several generalizations may be made. The carbon and 3.5 per cent nickel steels behave similarly in that rise in temperature is accompanied by a general decrease in ductility which is followed above the range 200 to 300 degrees Cent. (390 to 565 degrees Fahr.) by an in-

crease until at 550 degrees Cent. (1020 degrees Fahr.) values of elongation and reduction of area are greater than those observed at room temperature.

Elongation of the chromium-vanadium steel is about the same at 550 degrees Cent. (1020 degrees Fahr.) as at room temperature and does not show any very great changes throughout this temperature range whereas elongation of the nickel-chromium steel increases to a maximum at about 295 degrees Cent. (565 degrees Fahr.) or blue heat.

While the carbon and nickel steels are much more ductile at 550 degrees Cent. (1020 degrees Fahr.) than either the chromium-vanadium or nickel-chromium steels, as shown in Tables X and XI, yet the last two alloys have high ductility and the latter shows by far the greatest increase over its room temperature value.

The strength at fracture of the different steels tested, obtained by dividing the load observed at the moment of breaking by the reduced area, is shown in Fig. 6. While the data are incomplete and in some cases the variations in duplicate determinations are wide, the results are interesting when taken in conjunction with the changes previously described for at 550 degrees Cent. (1020 degrees Fahr.) the highest break-

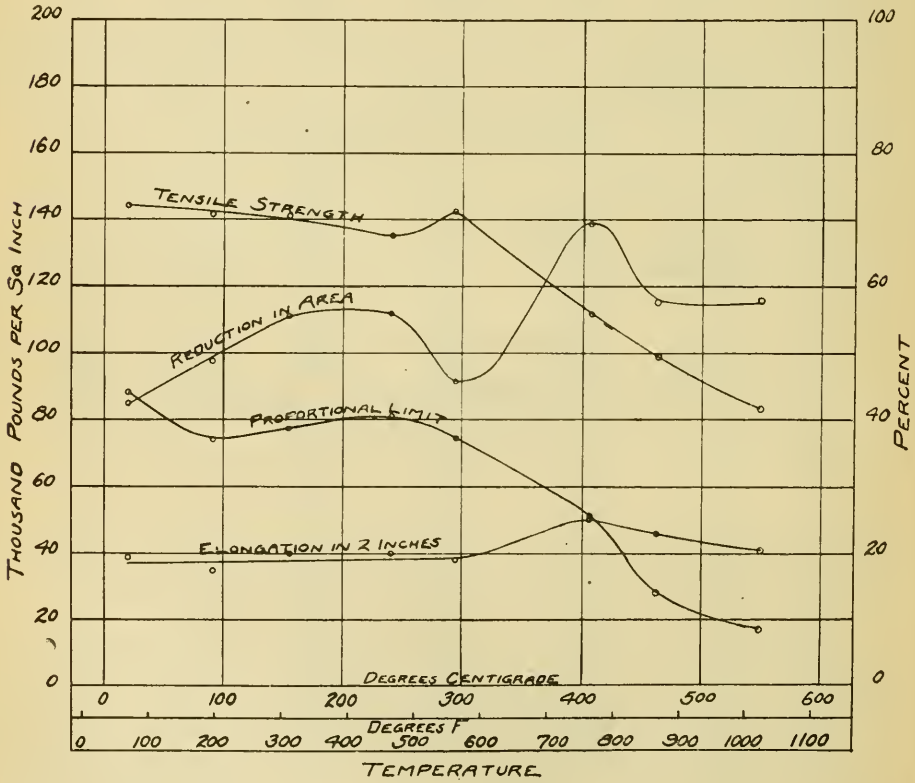

Fig. 5—Tensile properties at elevated temperatures of chromium-vanadium steel of the type 1 per cent chromium, 0.2 per cent vanadium and 0.37 per cent carbon

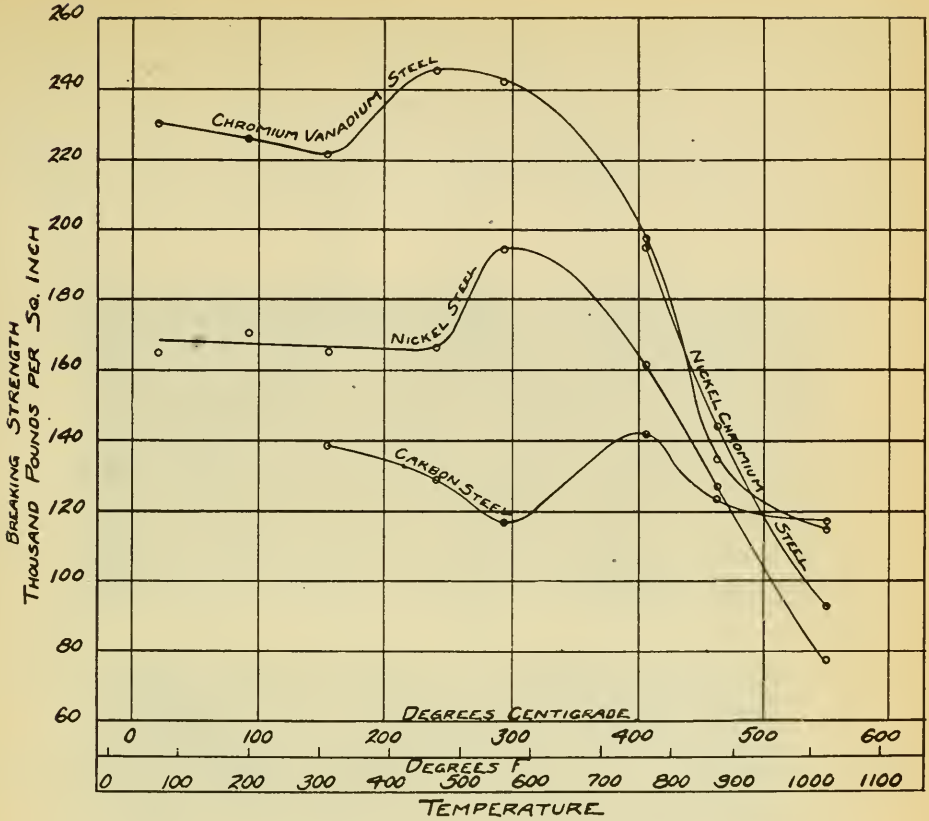

Fig. 6—Breaking strength at elevated temperatures of carbon, nickel, nickel-chromium and chromium-vanadium steels. Compositions of these steels are shown in Table III

ing strength is shown by the chromium-vanadium and carbon steels and the lowest value is observed in the alloy containing 3.5 per cent nickel.

The fracture of steels subjected to tensile stress at room temperature is transcrystalline while at high temperatures it takes place at the grain boundaries. The change from transcrystalline to intercrystalline fractures will occur beginning at temperatures somewhat above that of equal cohesion of the amorphous and crystalline phases, but the temperatures at which these fractures first appear in a given alloy depends upon the rate of loading[9]. The faster the load is applied, the higher is the temperature required to produce intercrystalline breaks.

Jeffries states that in most metals the equicohesive temperature occurs at about 0.35 to 0.45 of the absolute melting point so that for steels the change from fractures across the grains to those along the crystal boundaries should on slow loading first appear in the neighborhood of 550 degrees Cent. (1050 degrees Fahr.)

This temperature is approximately the highest at which tensile tests were made and as these were likewise considered of particular interest

9. Zay Jeffries: "Effect of Temperature, Deformation, and Grain Size on the Mechanical Properties of Metals." Trans. A. I. M. E., 60 (1919), p. 474.

from the standpoint of operation in the Haber process, specimens of the several steels tested were examined under the microscope to determine the character of the fractures.

Typical microphotographs are reproduced in Figs. 7 and 8 and while no general statements can be made with certainty, they show the tendency of the fracture in the carbon and 3.5 per cent nickel steels to follow the grain boundaries when broken at about 550 degrees Cent. (1020 degrees Fahr.)

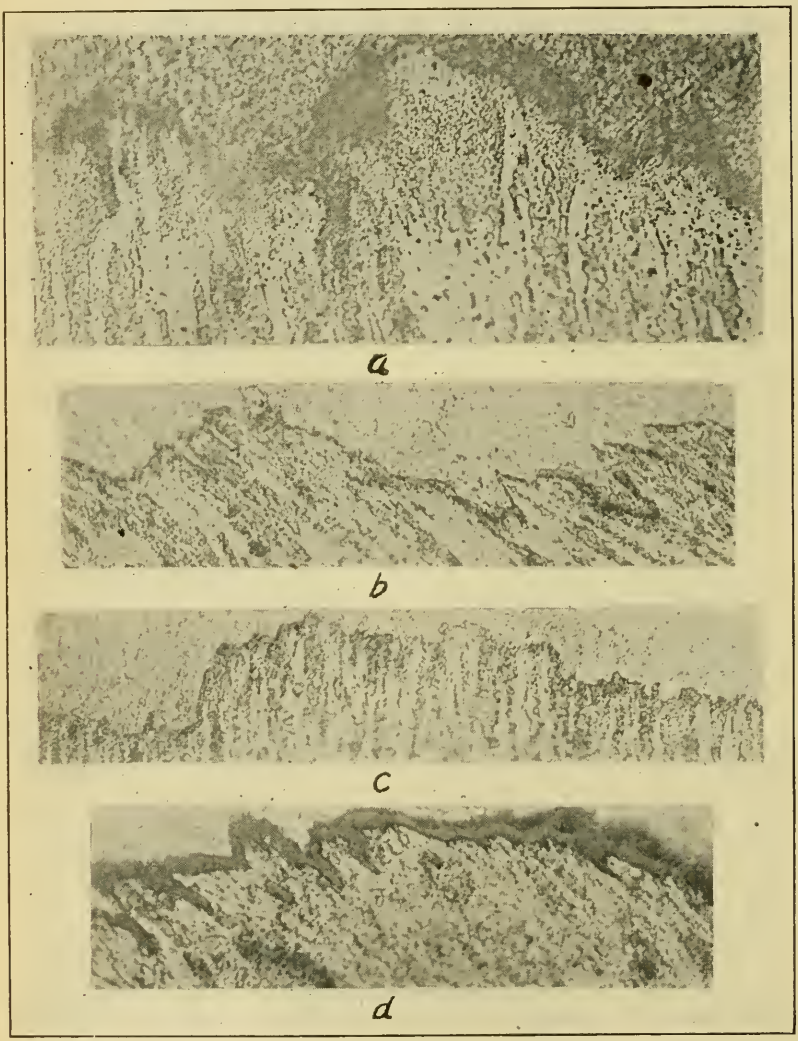

Fig. 7—Photomicrographs of fractures of carbon and 3.5 per cent nickel steels broken in tension at high temperatures. *a* is specimen A-16, broken at 463 degrees Cent. X 500. *b* is specimen A-22, broken at 550 degrees Cent. X 500. *c* is specimen B-11, broken at 463 degrees Cent. X 500. *d* is specimen B-24, broken at 550 degrees Cent. X 1000. All specimens etched with 5 per cent picric acid in alcohol

Table VI

Tensile Properties at Elevated Temperatures of Nickel-Chromium Steel of Type 3 Per Cent Nickel, 1 Per Cent Chromium, 0.4 Per Cent Carbon

	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium
Chemical composition, per cent	0.39	0.59	0.019	0.009	0.23	3.05	0.93

No.	Temperature of test: Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
C-14	Room		58,500	175,000	213,700	10.0	22.9
C-15	Temperature		58,500	171,800	207,000	11.0	25.2
Av.	21	70	58,500	173,400	210,350	10.5	24.0
C-2	92	...	84,700	175,000	.....	11.0	20.3
C-3	92	...	74,000	170,000	.....	11.0	23.1
Av.	92	198	79,350	172,500	.....	11.0	21.7
C-6	155	...	75,000	175,200	.....	12.5	23.2
C-7	155	...	72,500	166,000	.....	12.5	26.2
Av.	155	311	73,750	170,600	.....	12.5	24.7
C-4	241	...	63,500	181,300	.....	18.0	39.6
C-5	241	...	62,500	178,000	.....	....	....
Av.	241	466	63,000	179,650	.....	18.0	39.6
C-8	294	...	75,000	174,000	.....	23.5	62.4
C-9	294	...	80,000	171,000	.....	23.5	63.8
Av.	294	561	77,500	172,500	.....	23.5	63.1
C-10	407	...	43,000	127,600	181,200	20.0	66.5
C-11	407	...	49,000	132,200	209,000	20.0	65.4
Av.	407	765	46,000	129,900	195,100	20.0	66.0
C-12	463	...	22,000	105,000	137,700	19.0	59.9
C-13	463	...	21,500	102,500	150,300	19.0	62.0
Av.	463	865	21,750	103,750	144,000	19.0	61.0
C-16	550	...	12,000	72,100	90,000	19.0	59.0
C-17	550	...	15,000	69,500	95,750	22.5	67.3
Av.	550	1022	13,500	70,800	92,850	20.8	63.2

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

Table VII

Tensile Properties at Elevated Temperatures of Chromium-Vanadium Steel of Type 1 Per Cent Chromium, 0.2 Per Cent Vanadium, 0.37 Per Cent Carbon

	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Chromium	Vanadium
Chemical composition, per cent	0.37	0.74	0.020	0.013	0.21	1.04	0.17

No.	Temperature of test: Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
D-1	Room		88,000	141,600	236,000	20.0	55.5
D-16	Temperature		88,000	147,000	224,500	19.0	49.4
Av.	21	70	88,000	144,300	230,250	19.5	42.5
D-3	92	...	81,000	150,800	229,400	17.5	48.4
D-4	92	...	70,000	135,100	224,300	18.0	51.7
D-15	92	...	73,000	139,500	224,100	17.5	46.2
Av.	92	198	74,650	141,800	225,950	17.7	48.8
D-7	155	...	76,000	136,200	240,000	20.0	55.7
D-8	155	...	79,000	146,500	203,000	....	....
Av.	155	311	77,500	141,350	221,500	20.0	55.7
D-5	241	...	81,000	133,600	252,300	21.0	58.6
D-6	241	...	80,000	137,200	238,700	19.0	53.3
Av.	241	466	80,500	135,400	245,500	20.0	56.0
D-9	294	...	76,000	145,500	223,400	19.0	45.8
D-10	294	...	73,000	139,000	261,300	....	....
Av.	294	561	74,500	142,250	242,350	19.0	45.8
D-11	407	...	50,000	108,000	182,300	25.0	67.7
D-12	407	...	51,500	115,200	213,000	25.0	71.2
Av.	407	765	50,750	111,600	197,500	25.0	69.5
D-13	463	...	27,000	97,500	122,500	23.5	52.9
D-14	463	...	29,000	101,000	147,300	22.5	62.4
Av.	463	865	28,000	99,250	134,900	23.0	57.7
D-18	550	...	16,500	82,600	118,800	22.0	61.7
D-19	550	...	17,500	84,000	111,000	19.0	54.4
Av.	550	1022	17,000	83,300	114,900	20.5	58.0

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

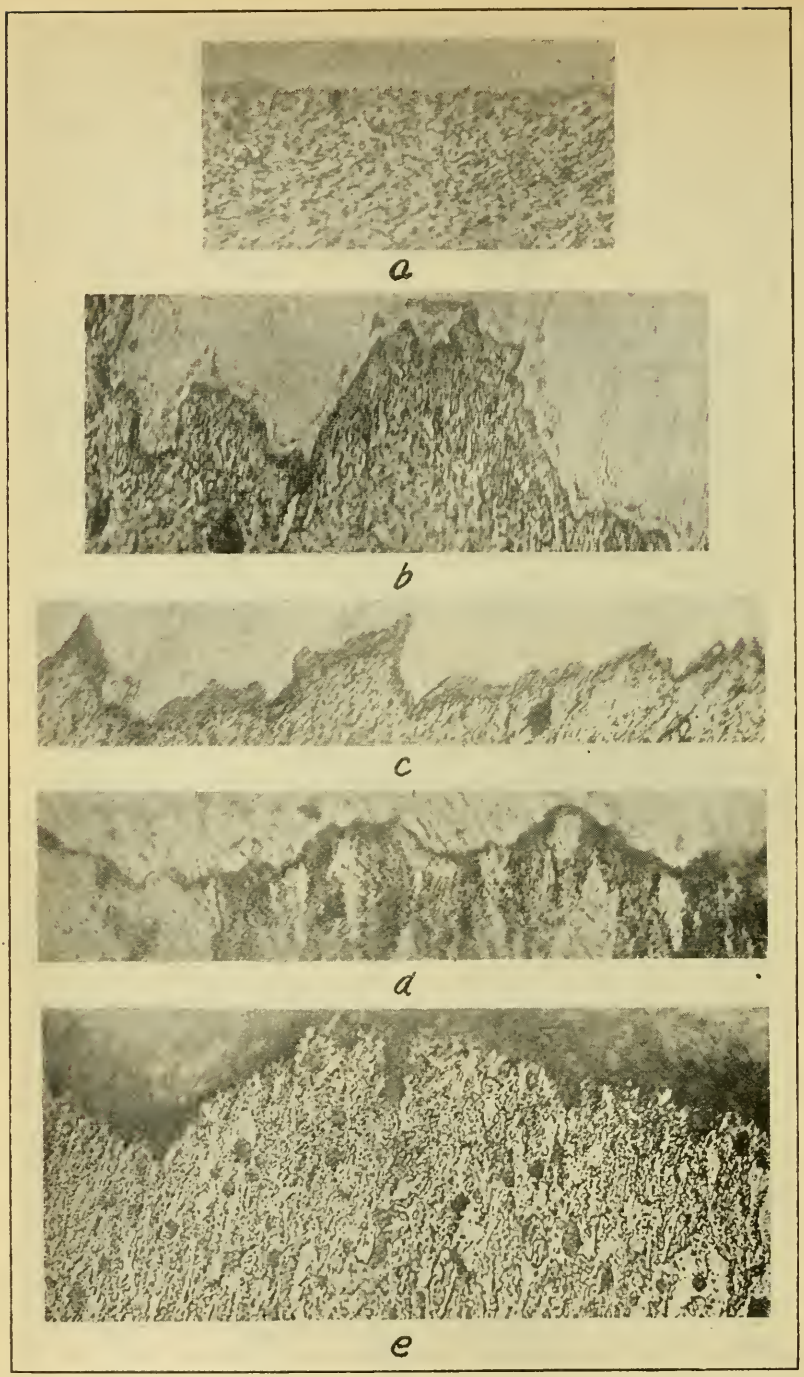

Fig. 8—Photomicrographs of fractures of nickel-chromium and chromium-vanadium steels broken in tension at high temperatures. *a* is specimen C-8, broken at 294 degrees Cent. X 1000. *b* is specimen C-13, broken at 463 degrees Cent. X 500. *c* is specimen C-16, broken at 550 degrees Cent. X 500. *d* is specimen D-14, broken at 463 degrees Cent. X 1000. *e* is specimen D-18, broken at 550 degrees Cent. X 500. *a*, *d* and *e* are etched with 5 per cent picric acid in alcohol; *b* and *c* with 2 per cent nitric acid in alcohol

The outstanding feature of the nickel-chromium steel is the fineness of the structure making it difficult to determine the character of the break, while in the case of the chromium-vanadium steel the fractures appear more nearly intercrystalline even at the highest temperatures under investigation.

The following points appear to deserve emphasis in connection with the tests previously described:

1. Of the four steels tested in normalized condition it appears that the two alloys containing chromium show greater resistance to weakening by increase in temperature to about 550 degrees Cent. (1020 degrees Fahr.) than either the plain carbon or 3.5 per cent nickel steels and at this highest temperature, the chromium-vanadium steel is to be preferred from the standpoint of high tensile strength and limit of proportionality.

Table VIII

Comparison of Tensile Strengths of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Tensile strength at room temperature pound per square inch	At 550 degrees Cent. (1022 degrees Fahr.) Actual tensile strength pound per square inch	Decrease from room temperature value Per cent	Ratio of tensile strengths with carbon steel as unity
Carbon	84,200	39,950	52.5	1
Nickel	104,250	35,350	66.0	0.9
Nickel-chromium	173,400	70,800	59.1	1.8
Chromium-vanadium	144,300	83,300	42.4	2.1

Table IX

Comparison of Proportional Limits of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Proportional limit at room temperature pound per square inch	At 550 degrees Cent. (1022 degrees Fahr.) Actual proportional limit pound per square inch	Decrease from room temperature value Per cent	Ratio of proportional limits with carbon steel as unity
Carbon	32,700	7,750	76.3	1
Nickel	51,850	8,250	84.2	1.1
Nickel-chromium	58,500	13,500	77.6	1.7
Chromium-vanadium	88,000	17,000	80.7	2.2

Table X

Comparison of Elongations of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Elongation in 2 inches at room temperature Per cent	At 550 degrees Cent. (1022 degrees Fahr.) Actual elongation in 2 inches Per cent	Increase from room temperature value Per cent	Ratio of elongations with carbon steel as unity
Carbon	30.5	40.5	32.8	1
Nickel	28.4	43.5	51.4	1.1
Nickel-chromium	10.5	20.8	98.0	0.5
Chromium-vanadium	19.5	20.5	5:1	0.5

Table XI

Comparison of Reductions of Area of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Reduction of area at room temperature Per cent	At 550 degrees Cent. (1022 degrees Fahr.) Actual reduction of area Per cent	Increase from room temperature value Per cent	Ratio of reductions of area with carbon steel as unity
Carbon	52.8	92.7	75.5	1
Nickel	46.7	88.9	90.3	1
Nickel-chromium	24 0	63.2	163.3	0.7
Chromium-vanadium	42.5	58.0	36.5	0.6

2. The carbon and 3.5 per cent nickel steels behave alike with rise in temperature and at about 550 degrees Cent. (1020 degrees Fahr.) the addition of the nickel appears to have a very small effect on the tensile properties of the carbon steel.

3. At 550 degrees Cent. (1020 degrees Fahr.) the strength and limit of proportionality of the chromium-vanadium steel is more than twice that of the carbon steel while the ductility of the former, as measured by elongation and reduction of area is about half that of the latter, though still quite high. However, at all temperatures below about 475 degrees Cent. (885 degrees Fahr.) the strength of the nickel-chromium steel is greater than that of the chromium-vanadium and both show higher strength values throughout the range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) than the carbon or 3.5 per cent nickel steels.

4. While no general statements regarding types of fractures can be made with certainty the tendency of carbon and 3.5 per cent nickel steels at about 550 degrees Cent. (1020 degrees Fahr.) is to follow the grain boundaries while at the same temperature the fractures of the chromium-vanadium steel appear largely transcrystalline.

In conclusion, acknowledgment is made to C. E. Lermond, mechanical draftsman, Ordnance Department, and T. E. Hamill, laboratory apprentice, Bureau of Standards, for carrying out the greater part of the routine tensile tests reported in this paper.

A UNIVERSITY COURSE IN METALLURGICAL ENGINEERING

By W. P. Wood

IN PREPARING the curriculum herein discussed the writer has had in mind the preparation of students not so much for the mining and mill end of metallurgy as for those industries which are concerned with the final shaping and preparing of the metal for use. A typical example of this type of industry is the manufacture of automobiles with all its allied interests. Such plants receive the metal as raw material from the mill and after fashioning it and probably heat treating it, assembled it in its proper position in the product which they are turning out. They are interested in the actual manufacture of the raw material only in so far as it affects the operations which they subsequently carry out upon the metal.

The writer has been influenced personally in laying out of this course by close proximity to these types of industry, and this leads to another point that may serve as additional support for a course which emphasizes the phase of metallurgy which has already been mentioned as having influenced the nature of this curriculum. It is felt that any institution which gives instruction in engineering should place emphasis upon the phases of industry which are of most importance in the territory from which the institution draws its support. Since institutions similar to the average middle western university have been in mind during the outlining of the course and as most of these schools are in close touch with the type of industry mentioned above, it is believed that this course could best be developed in one of this class of institutions.

Possibly the best means of presenting this material will be to outline in tabular form the course as it has been developed and then to discuss and clarify the reasons for arranging the work as it is. The question of credit has not been introduced for that is more or less a matter of detail and depends to quite an extent upon local conditions. The purpose here is only to indicate the relative emphasis and amount of time which should be placed upon the various phases of the course. This outline is shown in the accompanying table.

No doubt there are some subjects here included which some metallurgists would not include and some not included which might be preferred. This outline is only presented as a starting point for discussion. There is no question about the fact that discussion and criticism would bring out some very useful points in regard to the character and arrangement of material in such a course.

Certainly the first thing to be done is to justify the course in the review of elementary mathematics which appears in the first college year. One of the most discouraging things which the writer has been confronted with in his teaching experience is the apparent inability of the average university sophomore to make much application of the principles of percentage, ratio and proportion, etc., which he supposedly studied in the fourth grade. This also applies to work which involves

A paper presented by title at the Indianapolis Convention. The author, W. P. Wood, is assistant professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

the solution of quadratic and simultaneous equations. It is believed that a large proportion of university instructors have noticed the same thing. It is not thought that the secondary schools are altogether to blame. The difficulty comes in applying the principles of arithmetic, etc., to concrete engineering problems which arise, and it is just this which the writer has in mind concerning the course mentioned. Two objects would be accomplished: (1) The review of simple but not always familiar principles; and (2) an introduction to some simple engineering problems.

With regard to the mathematics which follow this first course mentioned, little need be said. It involves nothing more than a thoroughly trained metallurgist should have in order to handle intelligently the modern problems which are requiring more and more theoretical training.

OUTLINE OF COURSE

First Year

First Semester	Second Semester
1. Review of Elementary Mathematics	1. Algebra and Analytic Geometry
2. English or General Chemistry	2. English or General Chemistry
3. Descriptive Geometry	3. Descriptive Geometry
4. Language	4. Language
5. Shop Work	5. Shop Work

Second Year

1. Algebra and Analytic Geometry	1. Calculus
2. University Physics	2. University Physics
3. Language	3. Language
4. Qualitative Analysis	4. Quantitative Analysis
	5. Fuels and Combustion

Third Year

1. Calculus and Differential Equations	1. Kinematics
2. Organic Chemistry	2. Heat Engines
3. General Metallurgy of Iron and Steel	3. Machine Design
4. Physical Chemistry	4. Metallography of Iron and Steel
5. Strength and Testing of Materials	5. Metallurgy of Nonferrous Metals and Alloys

Fourth Year

1. Thermodynamics	1. Pyrometry
2. Furnace Design	2. Electrical Engineering
3. Engineering English	3. Special Metallurgical Problem
4. Options	4. Options

The writer is firmly convinced that the best road to complete mastery of a subject lies in the ability to make calculations involving the principles of the subject.

The shop work in the first year would include forge work and foundry practice. The aim should be mainly the acquiring of the shop atmosphere and methods. Supplementary recitations would serve as a means for introducing some of the simple theoretical considerations such as the presence of critical points in steel, reasons for forgeability of wrought iron and mild steel, and general effects of chemical composition upon the character of metals.

It is presumed there would be some argument about the language which occurs in the first two years. If this were a trade school course, language probably would not be included, but there is always a certain amount of culture which is inseparable from a university degree and this means the inclusion of some subjects which do not have a di-

rect bearing upon the subject and tend more to round out the student into a well informed man of the world. No one really could call himself a broadly trained metallurgist who has not some familiarity with at least one foreign language.

The physics in the second year would be similar in all respects to the present courses in university physics. There is less quantitative analysis included than is customary in many courses of chemical and metallurgical engineering. The writer believes that a metallurgist should understand the principles and practice of quantitative analysis, but does not necessarily need to become an expert in it. It will almost never be necessary for him to make routine analyses.

Study of physical chemistry should be elevated to a point of great importance. It might even be possible to call this course "physical metallurgy," but such a designation would not include the very useful and necessary review of chemical principles which physical chemistry involves. At any rate the course should make very clear the great application which physical chemistry has in the field of metallurgy.

In the fourth year, the courses with two or three exceptions are probably open to more criticism than most of those which precede. The writer believes, however, that thermodynamics should be included among the required courses, for the application of this subject to metallurgy is too little appreciated. The metallurgical engineer should also have some knowledge of the principles of electrical engineering and the necessity for this will become greater in the future as the use of electrical furnaces increases. The courses in pyrometry and furnace design might be included among options, but the writer is unable to see any situation where the metallurgical engineer will not have to concern himself with these subjects, particularly pyrometry.

The course entitled "special metallurgical problem" is no departure from the practice of the majority of engineering schools. It is here that the embryo engineer is supposed to obtain his practice in attacking a concrete problem in his chosen field. The value of such a course is well recognized and no doubt few people would wish to dispense with it.

In conclusion, one of the criticisms which would most probably be made of this curriculum is that there are not enough options. There is a danger in laying out a course of study which allows a too large number of options. The natural tendency for the average student is to elect subjects along the line of least resistance which leads to anything but a well rounded education. On the other hand, too stereotyped a course is not desirable since it leads to over specialization. The aim should be a happy medium between required work, and a choice of options which is wide enough to enable the student to become a broad minded engineer, without permitting such latitude that the selection of options becomes a mere searching for the easiest courses.

BUYING STEEL ON CLOSER CARBON LIMITS

By E. W. Pierce

OWING to difficulties experienced with steel sold under certain specification numbers allowing for a variation of carbon of ten points, a closer specification limit of as low as five points is advocated. This covers directly, steels heat treated for parts afterwards machined and steels used for carbonized parts. This particular demand is made as a means of reducing shop costs to the fabricator in the handling of material in the various shop processes.

Under the present mode of buying and selling steel based on the Society of Automotive Engineers' specifications, the carbon content of each specific grade is allowed a ten point range, that is a 1040 steel permits of steel running from 0.35 to 0.45 per cent carbon, and so on with the balance of the specification numbers.

On general appearances this permissible range seems quite satisfactory. It is especially of benefit to the steel manufacturer as it is obvious that it permits of less particular attention to the heats and gives him a greater range on which to fill orders. On the contrary it is not so favorable to the buyer who later must forge, heat treat and machine for use in the finished or fabricated state.

In the process of manufacture, each heat is numbered and the chemical analysis obtained is recorded with the heat number. The S. A. E. number for the heat can be given and the steel is so classed for storage or shipment. The steel is now ready to be used by the fabricator and to undergo the various processes necessary for its completion as a finished product.

The buyer, when ordering from the mill, gives his order in accordance with the S. A. E. specification requirements. The usual specification for a straight carbon stock for carburizing is S. A. E. 1020, permitting stock to be issued running from 0.15 to 0.25 per cent carbon. Lower amounts are often used and where possible to obtain such low carbon content, it is possibly better. To obtain a carbon content of 0.20 per cent is the usual practice, or at least from 0.15 to 0.20 per cent, and this amount always has produced excellent results for this particular work. However, when the carbon content approaches the upper limit of 0.25 per cent, the quality of the resultant product is considerably reduced. Higher carbon within the specification limits impairs the toughness of the part and makes it much more brittle under impact. Core refining heats, to some extent, may remove this trouble but not entirely.

Parts of delicate design and having thin surfaces to carburize require as low a carbon content as possible, as the hardening strains set up are greater than in the heavier constructed parts. High carbon stock of 0.25 per cent has been found to crack very readily under the above conditions. Lower carbon content increases toughness, increases resistance to impact and reduces the danger of cracking in hardening.

Now let us take, for example, an order calling for a 1040 steel. The steel plant can fill this order with a product having a carbon content

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A paper presented at the Indianapolis Convention. The author, E. W. Pierce, is chief metallurgist, Maxwell Motor Co., Newcastle, Ind.

anywhere from 0.35 to 0.45 per cent, and suppose it is filled with that having a 0.35 per cent carbon content. They are perfectly justified in so doing. But suppose the mill cannot supply this material all from one heat and it is necessary to use material from other heats; then there comes the danger of supplying steel which varies considerably from the analysis of the original heat but within the specifications, say 0.43 per cent carbon. We would then have a steel shipment of a 1040 grade which would have a carbon variation of 0.08 per cent.

When the material is received in the forge shop of the buyer, it is cut to length, stacked and marked as 1040 steel and later delivered to the hammer as such. In the forging, however, no great difference is noted as the forging heats are usually high enough to insure easy working of the steel. During the process of shipping, cutting and stacking and delivering to the hammer, and further in the forging operation itself, the steel becomes thoroughly mixed and the material, although possibly shipped in two grades of 1040, is now inseparable.

In this condition it is brought into the heat treatment to be hardened and drawn to meet the various tests prescribed by the engineering department. These tests, as you know, cover the various physical tests and hardness tests. Further than this, the product, as it comes from the heat treatment, must be uniform in all respects and particularly as regards machinability. Too great stress cannot be put on this latter quality as it is directly responsible for the rate of production and the efficiency of the machine shop.

The evils of nonuniformly machinable steel are many and costly. First, the product itself will vary in quality and service to the ultimate consumer, the one place where it must make good. This, however, may be classed as an indirect evil. The more apparent and the more to be considered faults to the manufacturer are increased tool costs due to breakage and burning, waste of time of operator in changing and regrinding tools, waste of material and, further and most important, decrease in production.

Nonuniformity in hardness is, of course, the direct cause of many machine shop troubles and is due to the manner in which the material is hardened. The better hardening conditions require quenching at or just above the critical temperature to insure good structure as well as good physical properties. It has been found that steel, varying as much as 0.08 to 0.10 per cent carbon on hardening, will produce quite a variety of results as regards hardness. Actual tests have shown a scleroscope difference of 15 to 20 points where the variation is as much as 0.10 per cent.

Therefore, it is obvious that material varying on a ten point limit cannot be hardened satisfactorily and give the proper structure as well as physical properties with the proper hardness. In cases of this nature, it is impossible to draw back a heat evenly and give it uniform hardness.

Many small parts often require as high a hardness as is possible with good machine shop practice. On heat treated work which is passed on a 10 per cent scleroscope inspection and using a grade of steel varying as pointed out above, it is practically impossible to maintain the required high hardness without a few parts getting by which will give trouble in machining. In order to get by this trouble it is a case of giving the entire product a 100 per cent inspection.

With this remedy for surmounting the difficulties of uneven hardening, additional costs have been added to factory expense or overhead, as inspection is usually charged to this account. In either case, the cost of handling steel of such wide variation is of considerable consequence and is well worth looking into. As a means of eliminating the entire expense to the manufacturer, whether charged to production or overhead, let the buyer require that his steel be sold on closer specifications, and further, that the carbon content be maintained within a five-point limit.

This requirement on the steel mill is not excessive and is, in fact, being done at some mills at present. This closer limit can be obtained through the better methods of manufacturing by which the steel is more absolutely controlled. With better determined loss of constituents, it is possible to make a steel within the carbon limits, as well as within closer limits on chrome and nickel. Further, improved methods in casting will cut down carbon segregation within the ingot itself.

Discussion of Mr. Pierce's Paper

MR. PIERCE: At the time the industrial depression took place our company, as well as some others that I have been familiar with, was found to have an unbalanced inventory, which was particularly noted in the material stocks. During this time of depression and readjustment, it has been necessary to work off this material in the best manner possible. Therefore, we took a very thorough inventory of our stock and found that we had considerable quantities of various grades of steel, very much within the same carbon limits, but still varying considerably, which would give us trouble later on.

It had always been our custom to buy our steel and have the lot number and the heat numbers accompany the shipment, and the material was always stacked and sorted in this manner. But when it came to readjustment these various quantities were selected according to S. A. E. specifications, as nearly as possible and stacked as such. During the time after that, during our production, we had considerable trouble with the heat varying in carbon content, which gave us trouble in the hardening room as well as in the machine shop.

Therefore the idea seemed to be that it would be much better if the specifications could be narrowed down and brought down to at least a five-point limit. In this manner we believed that we would eliminate considerable shop trouble throughout the plant in the hardening room, as well as in the forge shop. Thus this short article has been written arguing for a five-point limit on steel for carbonizing purposes as well as heat treatment.

MR. STAFFORD: I would like to ask the speaker if he has been able to buy any steel, ordinary hard steel, where he could specify a five-point limit?

MR. PIERCE: We have been able to do that recently, owing to the fact, I suppose, that there is greater competition in manufacturing and in selling. I will admit that previous to the last few months we were not able to do that, but it is an actual fact that we have bought steel on those terms. I might say further that where the range of ten points is allowed, it often happens that shipments will come in that are, say, two points under or even two points above, and it is very rare

that they are turned down on a two point basis. Allowance usually is made for this amount. Therefore, practically the variation is as high as 14 or 15 points, whereas if the steel can be kept and bought within a five-point limit, if it cannot be absolutely controlled within the five points, we are absolutely sure that it will be within the ten-point limit.

Further than this, it is impossible on a large production scale to harden heats individually and follow them through the shop because it requires that each particular heat must be kept separate so that it can be treated properly, and when it comes into the machine shop it also requires additional attention in the setting up of machines for proper and efficient machining. So where we can rely on the fact that our scale will come within these limits, the operation in the heat treatment and in the machine shop itself has been reduced, as regards costs and efficiency of handling.

A SUCCESSFUL BONUS SYSTEM APPLIED TO HEAT TREATING

By A. A. Blue

IN general, so-called bonus systems are developed primarily, with the purpose of increasing quantity of production and secondarily, increasing quality of production, or a combination of the two, resulting in increased returns to the plant owners, the activating agent being increased pay to the men employed upon the work. The fundamental principle involved is simply one of stimulating the worker's interest in his task, for no one can do anything well in which he is not really interested, hence we have bonus systems, golf tournaments and world's baseball series. However, no one feels an interest in any competition or effort which he does not believe to be fair, and in which he lacks confidence as to its stability. Lack of care and study in the past with respect to installing bonus systems and setting rates has caused a natural and wide spread distrust of such matters to grow in the minds of most men.

These systems can only attain the maximum degree of success where the management has taken every precaution to establish equitable rates, and has then developed a reputation for maintaining these rates. Rates that are too low naturally fail to interest the men, and rates that are too high work an injustice to the management, and further injure the workmen as well. There is an inherent sense of the fitness of things in everyone, to a greater or less extent, which will show itself in time in some manner or other, so that the average man receiving an excessive rate cannot long be content and maintain the necessary interest in his work, and the employer will shortly lose a formerly good man, and the man lose a job that was too good for him. This has been an all too familiar occurrence during the war period. Such conditions are injurious to all concerned and cannot be too carefully guarded against.

Turning from general principles, there are a number of practical details that must be satisfactorily taken care of in any successful bonus system, thus, (1) the figures must be easily and cheaply calculated and they must be accurately obtained; (2) the flexibility of the organization should not be greatly affected by such an installation; (3) it should apply to all articles manufactured, that is, it should cover a large variety of products; (4) it must obtain co-operation between all employes, those on the same shift and those on all shifts; (5) complete records should be kept of all details, preferably by the men themselves, with suitable checking, as it is only human nature to do one's best when the results go down on paper and are received by one's superior.

The bonus system described in the following paragraphs has been worked out on the general principles outlined above, and applied to a heat treatment department with marked success. Heat treatment, being pre-eminently a quality operation, this aspect has been emphasized to a high degree, as compared with quantity. The actual details are embodied in the following announcement, issued to the men in the department over a year ago:

"The following bonus regulations will be in force for the men in the heat treating department:

Heaters: Heats are to run according to the following regulations:

(1) Temperature: The temperature, after the material is soaked out, must be

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A paper presented at the Indianapolis Convention. The author, A. A. Blue, is metallurgist, Duff Mfg. Co., Pittsburgh.

kept within these limits:

Annealing and carbonizing: Plus or minus 20 degrees Fahr.

Quenching and drawing: Plus or minus 10 degrees Fahr.

(2) Time: The times for heats in the various furnaces are as follows: No. 1 and No. 2 furnaces—Soak out in 1 hour, hold ½ hour, total maximum time not over 2 hours. (Similar figures were included for other types of furnaces.)

The number of heats run by each heater within the above limits will be figured on a percentage basis for a week's time and bonus paid as follows:

Efficiency Per Cent	Bonus per hour	Efficiency Per cent	Bonus Per hour
90	$0.005	96	$0.06
91	0.01	97	0.07
92	0.02	98	0.08
93	0.03	99	0.09
94	0.04	100	0.10
95	0.05		

The temperature will be taken from the record on the pyrometer. In case of instrument trouble, the heat will not be considered either way, unless the heat was "off" before the trouble occurred.

The above times are on the basis of the following minimum weights per furnace charge:

No. 1 and No. 2 furnaces—300 pounds, etc.

(As above, similar figures were prepared for each type of furnace). The time will be counted from the last piece charged into the furnace to the first piece pulled out and shall be so entered by the foreman on the ticket. The foreman shall inspect all heats when "soaked out" and note this time on the tickets, also. Each heater will be required to run from 1 to 4 furnaces.

In case of a heat running from one shift to the next, the heater having run it the greater length of time will be responsible.

Exceptions to the above are (1) die blocks; (2) ball races; (3) shear blades, where the temperature only will be considered.

The above times are based on the continuous operation of a hot furnace, and do not apply to the first heat in a cold furnace, when the temperature only will be considered.

Helpers: Helpers will be paid a bonus on the following basis:

Pounds per furnace-hour	Bonus per hour	Pounds per furnace-hour	Bonus per hour
170-180	$0.01	220-230	$0.06
180-190	0.02	230-240	0.07
190-200	0.03	240-250	0.08
200-210	0.04	250 and over	0.10
210-220	0.05		

These figures are obtained by dividing the total weight of material handled during the week by the number of hours all active furnaces are in operation. When all work for a furnace has been completed, this fact will be reported by the foreman and the furnace will not be counted as active again until more work arrives.

The figures are "over-all", taking into account all work done, that is, carbonizing, annealing, quenching, etc. Men on both shifts will receive the same bonus. Work handled twice will be considered as double weight, that is, material quenched and drawn back will be counted twice. Likewise, material double-quenched will be counted twice.

Work which fails to pass test on standard treatments will be retreated to pass without credit being received towards the bonus.

The weight handled will be based on the count made by the inspector and each ticket must bear the inspector's OK for the count.

Foremen: The foremen will each receive 10 per cent of the total bonus in the department.

No man will receive any bonus for any week in which he has been absent, unexcused."

The conditions obtaining in the department to which this system was applied cover a wide variety of work, such as (1) all types of commercial drop forgings for the automotive and other trades; (2) all vital steel parts used in the manufacture of various types of high grade lifting jacks, such as carbonized gears, high carbon, high chrome ball races, nickel

chrome pinions, lifting racks, etc.; (3) drop forge die blocks, trimming knives, etc. Three types of furnaces are used, necessitating different standards as to weight of charge and time of heating for each type. A well known recording potentiometer system is employed for measuring temperatures, one thermocouple being suspended in the front and one in the back of each furnace, the ends of the couples being in actual contact with the charge in the furnace at all times from the moment the charge is in place until it is ready for removal. Immediate discharge is the penalty for anyone tampering with these couples during the operation of a heat.

Form 322 5M-1-21

DUFF MFG. CO.

HEAT TREATING DEPT.

Part No. AB-418 Name Connecting Rod Qty. 150

Count OK. Mar.

OPERATION	START	SOAKED	FINISH	CHECK NO.
Charging				
Annealing				
Carbonizing				
Quench	830 AM	940	1010	283
Draw	1100 AM	1155	1225 PM	283

Date 8-25-20 Shift Day Furnace 3-619-4

Treatment 1600 – Water

1080 – draw

J. Jones

REMARKS ON BACK FOREMAN

Fig. 1—The standard form or ticket for each lot of material treated, giving spaces for entering all information concerning the nature and quantity of the heat itself, together with data as to length of time in furnace, heater's check number, date, treatment and the furnaces employed. The number following "Furnace" indicates the furnaces used and the heat number, thus, here the heat number was 619; the first heat was received in furnace No. 3 and the second in furnace No. 4. All such records are gone over by the foreman of the shift and personally signed by him before being turned into the office. The inspector then checks the count made of the number of pieces, making the necessary notation of the face of the report

The men employed are, as noted above, divided into heaters and helpers. The former have to do only with heating the furnaces, superintending the location of the charges in them, and keeping the burners, etc., about the furnaces in condition. The latter do the heavy work, such as charging the furnace, pulling the heats, quenching, etc. A foreman is, of course, in charge of each shift.

Referring now to various features mentioned in the introductory paragraphs, and examining them as applied to the present instance, we find,

(1) *Quality*. The heater is chiefly concerned with the quality of the

product, as measured by the accuracy of the temperature control. Actual figures of the results obtained are as follows: The first week in which the system was in force showed two typical heaters with averages of 74.5 and 81 per cent. The second week their figures were, respectively, 97 and 96 per cent; the third week, 95 and 96 per cent. In a year's time, covering all sorts of conditions of business, labor, etc., in only two instances has the maximum been reached and in three cases have heaters failed to make some bonus. The general effect can be compared closely to the governor on an engine. If a man has been averaging 95 to 96 per cent and becomes a little careless, with a resultant drop to 90 or 91

Table I

Bonuses Earned in Week Ending Sept. 25, 1920

Heaters

Name	No.	Efficiency per cent	Rate of Bonus
Murphy	219	87	No bonus
Lewis	225	95	$0.05 per hour
Jenkins	230	96	0.06
Ross	283	94	0.04

Helpers

Total weight handled, pounds	162,444
Total furnace hours	692
Pounds per furnace hour	235
Bonus rate per hour	$0.07

This rate applies to

Name	No.
Lutz	218
Lehman	220
Kopf	222
Hindman	231
Salvo	270
Livitz	250
Kimick	242
Marunchek	234

Foremen

Total bonus for week	$45.00
10 per cent of same	4.50

This applies to

Name	No.
Welty	278
McGregor	272

per cent, the effect upon the following week is always most marked, as the increased attention resulting from the lower figure invariably results in a very good week with possibly 98 per cent average. The temperature limits prescribed are well within the range of possibility for ordinary shop furnaces, and at the same time, amply close for accurate heat treatment. In some cases, of course, such accuracy is not entirely necessary, but the effect of impressing upon the men the need of such care in each and every case cannot be overestimated, as it is only upon such a foundation that constantly reliable results can be obtained. In most instances, even where the recorded temperatures do not fall within the specified limits, the divergence is so small that the work will pass test anyhow, and the instances of retreatment have been very few indeed.

Quality is also taken care of by the helpers to the extent that they are held responsible for the proper quenching of material, inasmuch as any parts failing to pass test after receiving a well established treat-

ment, must be retreated without credit being received for the weight handled. This circumstance, too, has been met with in less than a dozen instances.

(2) *Quantity.* In addition to his quality concerns, the heater is further interested in quantity to the extent that he must run out a

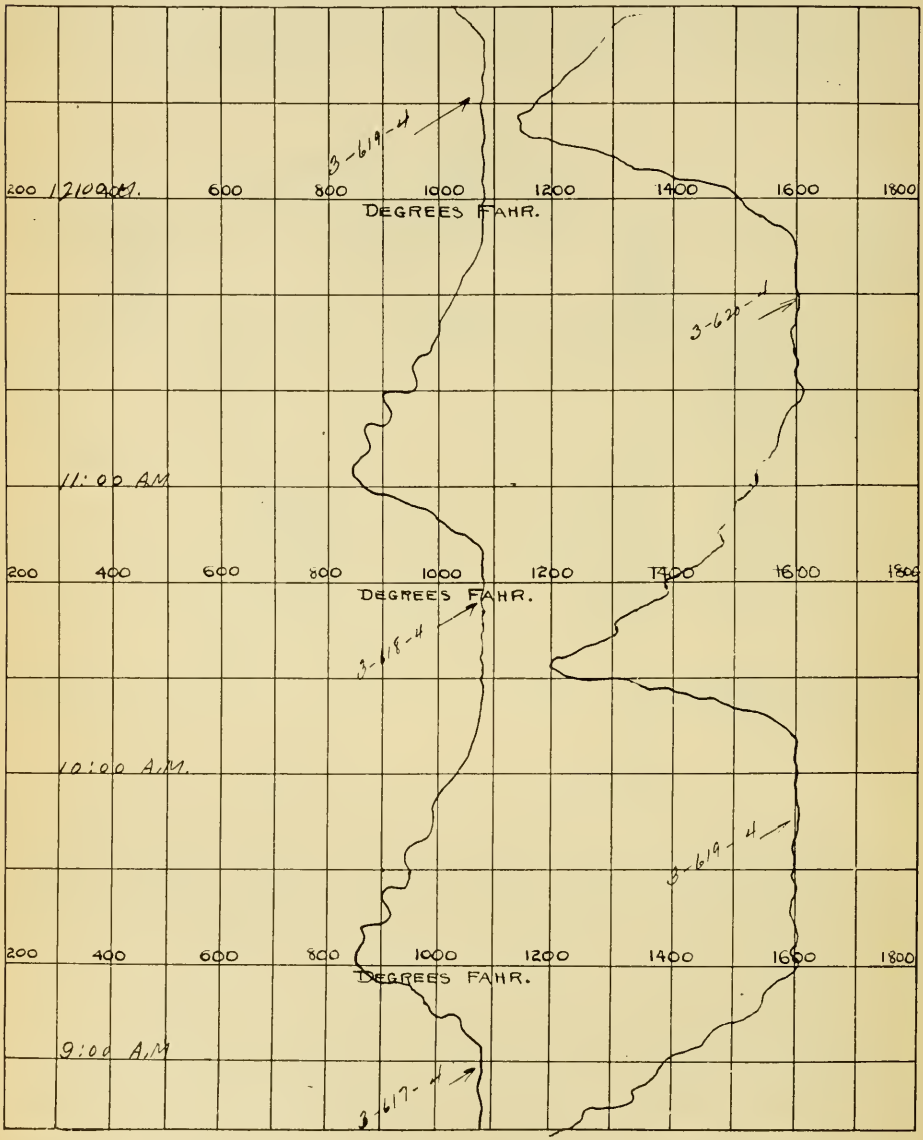

Fig. 2—The report shown in Fig. 1 is checked in the office against the record chart of the furnaces. Above is shown a portion of such a chart, showing the simultaneous records of two furnaces, No. 3 and No. 4, the former at the quenching heat of 1600 degrees Fahr., and the latter at the draw temperature of 1080 degrees Fahr. The accuracy of these temperatures is noted and, if within the tolerance allowable, bonus is credited towards the heater concerned. The various heats are at the same time identified with their respective numbers to facilitate future reference

heat of a certain weight in a definite time to score on his average for the week. The helpers, however, are primarily interested in quantity, and it is at all times to their advantage to clean up the work promptly, the bonus being paid upon a compound unit, involving not only weight but time. The heaters and helpers act as a "check and balance" system, the one on the other with respect to quantity, it being to the heater's advantage to charge the furnace as near as possible to the low limit, so that he may more readily meet the time element, and the helper's advantage being best served by a maximum load in each furnace. Practical results from the quantity viewpoint are as follows: Previous to the installation of the system, the "pounds per furnace-hour" were found to average 150 to 160. This was felt to be low, reference to the above tables showing the higher values actually determined upon. The following figures were realized in successive weeks after putting in force these regulations: 245, 249, 235, 208, etc. These rates have, indeed, been very happily selected, as the men have in every instance made some bonus, and, up to the present time, have not yet succeeded in reaching the maximum.

(3) *Ease and accuracy of computation.* All the necessary figures to compute the bonus rates are obtained from two records, one, Fig. 1, being a record or "ticket", made out for each furnace charge, and the other, Fig. 2, coming from the automatic record of the potentiometer. The importance of records in heat treatment work can scarcely be overemphasized, so that these two forms are, in the writer's opinion, necessary to any well-run department whether using a bonus system or not, and they are not, therefore, any burden chargeable to such a system itself. These "tickets" and furnace records are gone over each morning in the office for the previous 24 hours, and the weights and good and bad heats readily recorded. At the end of the pay period, it is a simple matter to obtain the final figures. The unit, "pounds per furnace-hour", is not a sensitive one, and when taken in groups of ten, a small variation in time or weight produces no appreciable change in the result. The inspector's count of material handled insures accuracy as to weight, and the temperature chart is made automatically by a machine under lock and key. Table I shows a typical report of a week's bonus for the men.

(4) *Flexibility of system.* In general, most work of a large heat treating department is of standard material. In cases, however, where such is not the case, the time element on heats is waived, and temperatures only are considered. This is noted in the announcement quoted above in respect to die blocks, etc.

(5) *Variety of work covered.* The range of work to which this system is applied is quite large, as noted above, and very careful study was made to secure figures that should be applicable to a wide line, such as ordinary annealing, hardening, and special work as die blocks, carbonizing, etc.

(6) *Co-operation of employes.* This desirable feature is largely obtained by clubbing together the bonuses of both shifts. Thus, there is no tendency for one shift to leave the shop in a poor condition for the incoming men. It is also to the advantage of the foremen to maintain harmony throughout, as their own bonuses depend in turn upon

the amount of the bonus which is earned every workman in the organization.

Two criticisms that may be urged against the present plan come to mind as follows: First, in the case of absence of a helper, additional work is thrown upon his associates with the probable result of a lessened bonus and more work per man. In practice, however, it has been found that the penalty attached to absence has practically negatived this consideration. Second, it may be felt that the helper should not receive the same bonus rate for handling one heat per day in slack times, as for six in busy times. In such a connection, it should be considered that by their handling the work promptly and not "lying down" so as to lengthen it out, the fuel necessary is reduced, less scale is formed upon the product, and the wear and tear upon equipment is minimized. It has thus been the writer's experience that such a provision is justified in the long run.

The success of the above installation has been due, as explained in the opening paragraphs, to being in happy accord with the underlying principles involved. All rates and figures were set as the result of over six months careful study of all conditions. The result has been most fortunate in that they have never been altered, the men thereby have confidence in the management, and while making some bonus every week, have scarcely yet attained the maximum, giving a constant incentive and maintaining the interest. Aside from the money stimulant, it is of considerable satisfaction to Mike to know that he ran 96 per cent of his heat correctly, while Joe got but 93 per cent, the records being made automatically under their own eyes. The men pay much more attention to the condition of their furnaces, too. Dirty burners and loose bricks do not aid in running accurate heats and are promptly attended to. The helpers always have a charge of material waiting beside the door of each furnace ready to go in the moment the present charge is removed.

All this is done with a relieving reduction in personal friction, haggling and other such disagreeable features so prevalent under other conditions, so that the system may almost be regarded as automatic. This is simply due to the fact that right or wrong is so sharply defined. Either a temperature record is OK or it is not, and having been automatically made by a reliable machine, cannot be disputed. The weight report is dependent upon the count of an impartial inspector under a chief inspector, and no argument arises from this source. The men know if they work hard, they will receive a fair bonus, and if they do not, they get no bonus, so that they go to it. Practically the only friction caused by the regulations came in the first week, when two men quit, after being refused bonuses on account of absence. The rule was strictly adhered to and has caused no trouble since.

The system just described has been of considerable value to the author, and it is hoped it may contain suggestions that may prove of value to others in similar work.

THE HEAT TREATMENT OF STEEL CASTINGS

By Walter H. White

ALL steel castings, no matter by what process they are made or for what use they are intended, should be treated to relieve the strains set up during solidification. Success can be had with various types of furnaces, the principal requisites being:

1. A uniform temperature should exist throughout the entire heating chamber.
2. The furnace should be always under control of an experienced operator.
3. The pieces should be heated uniformly from all sides.
4. A temperature indicating instrument should be used in every case.

Solid fuel, oil, gas or electricity may be used for heating. Heat converted from electric energy is the cleanest, safest and easiest controlled, but in most cases is too expensive.

Where castings of a like size and like composition are treated day in and day out, if the quality of steel is good the heat treatment department can soon establish a practice that will accomplish good results and pass any necessary tests that are required. It is in the jobbing shops making castings weighing from 10 pounds to 50 tons and bearing different compositions that the heat treatment department has its trouble, and for this reason specifications should be outlined and the melting department should be compelled, in so far as it is practical, to furnish castings within these specified limits. These limits, of course, are made according to the work required of the particular casting in question.

Many workmen operating heat treating furnaces know how to load their furnace; that is, how to place their castings so they will not distort; how to control their fire and how long to heat and soak. This knowledge has been gained through experience which has cost some company many dollars before this particular state of perfection has been reached. Many of these same men, if in their early days of experience had been trained under more scientific methods and taught enough of metallurgy to give them the knowledge of why they heat to a certain degree and why they soak for a certain time, would have saved money for the company and would have improved their personal knowledge of steel treatment, thus fitted themselves for better positions. It reminds one of the story of the old railroad man who was being retired after 30 years of faithful service. The officials gave a banquet in his honor and each had something to say in his behalf, giving figures as to how many thousands of wheels he had inspected, how many hammers he had worn out and how many miles he had walked. One official finally asked him why he struck this steel wheel with the hammer, and he answered, "In all my years, I never knew." So it is with some of the old time furnace operators, only it may not be so bad as this particular case. Some steel men who have gained a certain amount of knowledge have been reluctant in giving the other fellow the benefit of their experience and thereby to promote the progress of the steel industry. This type of man is fast disappearing and with his disappearance, progress is being made.

A paper presented by title at the Indianapolis Convention. The author, Walter H. White, is superintendent of melting shops, United States Naval Ordnance Plant, Charleston, W. Va.

First, when a heat of castings is passed to the heat treatment department, chemical analysis should be known and each casting, no matter how small, should be stamped with the particular melt heat it was cast from. Second, the department should know the physical results desired and possible from these castings. Third, the department should know the classification of size and chemical composition; that is, carbon and manganese of a maximum and minimum content for each heat treatment. The results under this practice will be more consistent if the practice is outlined by the proper persons and the operation carried out according to instructions.

Better results are being accomplished today in the shops where electric control instruments, such as indicating pyrometers, recording pyrometers and automatic control boards, are in use than in the shops where such instruments are not being used. The progress made has been excellent, but is not due wholly to the use of scientific instruments, special design of furnace or individual efficiency of the heat treater, but due in part to a better steel being made by the steelmaker. It is impossible for the heat treatment department to obtain certain standard results from all castings sent to them for treatment, even though they are all of the same design and composition. The history of the melt, which begins with the charge selection and ends with the shipment of the heat, covers a passage that has many problems, which if not solved properly by the steelmaker, causes the steel treater no end of trouble, for it is impossible for him to treat bad material but possible for him to get excellent results from good material, if these problems have been solved.

Of all the steel melting furnaces used for the manufacture of steel castings and forgings, the electric furnace offers to the steel industry the best unit for the steel treater. This is due to the following reasons: The best range of composition can be set and the limits made to a minimum. Eight points of carbon, 10 points of silicon, 10 points of any other alloy with a maximum of 0.02 phosphorus and 0.02 sulphur is a sufficiently close range for any electric melt shop to work on. The writer is connected with one of the largest electric furnace plants in the country and with the above allowance, making most alloy steels, can vouch for the fact that not more than two off heats have been made in the past year.

A. N. Canarroe in his paper published in the April, 1920, issue of the *Steel Treater's Journal,* touches on many defects that can happen in steel castings due to melting practice, and any one of the many he mentioned is sufficient to make the steel treaters' results unsuccessful. The first he speaks of is temperature, and this is one of the most important. When one speaks of electric steel they think of it as always being very hot because the electric arc is possible of intense heat, but that is no reason why the steelmaker cannot control his temperature for tapping. Duplex heats from the open hearth to the electric are being made where the tapping temperature from the open hearth furnace is hotter than the tapping furnace temperature of the finished product from the electric furnace.

It is believed most open hearth and electric furnace plants have been pouring their castings at too high a temperature, and where the defect does not show on the surface as a crack or check, due to ratio of solidification of heavy and light sections, it is in the casting as an excessively large crystal, due to the steel holding temperature in the granulating range for too long a time. This is due primarily to too high a casting

temperature. Another serious trouble is the blow hole which may be due to improperly dried molds or the steel not being properly killed or deoxidized.

The question of working the steel in the liquid charge to eliminate certain injurious gases, covers a large field and would come under another subject. The question of wet and improperly vented molds is a simple problem and due in the majority of cases to lack of judgment on the dry floor foreman's part. Sonims or solid nonmetallic impurities can be controlled to a minimum by not using aluminum, or using it sparingly; good clean ladle practice; the use of high grade refractories; clean mold practice; judgment in selection of charge and balanced composition of finished product; and above all, absolute control of the melting heat from power on to tap with proper slag conditions existing when the heat is ready to pour.

No trouble was experienced on the following steel castings weighing 6000 and 600 pounds respectively:

6000-Pound Solid Round Casting Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent
0.32	0.73	0.25	0.021	0.017	3.15

Treatment

Heated to 1500 degrees Fahr., soaked 6 hours, quenched in water.
Heated to 1250 degrees Fahr., held 8 hours, cooled in furnace.

Results

	Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
Required	85,000	53,000	22	35
Obtained	97,800	75,600	22	39

120-degree cold bend satisfactory

600-Pound Cone Shape Casting Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent
0.36	0.75	0.21	0.019	0.011	3.08

Treatment

Heated to 1500 degrees Fahr., soaked 6 hours, quenched in water.
Heated to 1250 degrees Fahr., held 6 hours, cooled in furnace.

Results

	Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
Required	85,000	53,000	22	35
Obtained	97,100	70,800	24	45.3

120-degree cold bend satisfactory

With good steel and the above treatment, it was possible to pass 98 per cent of castings of the above composition submitted for test.

The following results were obtained from a simple steel casting weighing 300,000 pounds:

300,000-Pound Steel Casting

Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent
0.26	0.66	0.17	0.028	0.025

Treatment

Heated to 1750 degrees Fahr.	Hours
Time to reach temperature	40.5
Time of soaking	48
Held after soaking	30
Cooled in air	
Furnace closed	27

Furnace opened	5
Furnace closed	28
Low oil on	12
Cooled in air	
Furnace closed	74

The above treatment required 11 days. As the casting was only partially cleaned, it was finally finished and recharged for the following treatment:

	Hours		Hours
Time to reach 900 degrees Fahr.	17	Held	2
Time to reach 1270 degrees Fahr.	8	Held	5
Time to reach 1600 degrees Fahr.	12	Held	55

Cooled in furnace for 6 days.

Results

Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
65,000	23,000	24	45

The length of time and the care taken in the above treatment was necessary to insure the physical results and to prevent the casting from cracking during treatment.

H. S. Wilson's advice as to taking small samples of bar steel as received from the mill, place them in the furnace, and as the heat rises to remove them one at a time at various stages—the last one, if possible, at the burnt stage, is well worth trying on many classes of stock steel. As he plainly brings out the fact that transition from hard to soft is in an extremely short range, it is possible to cast from each melt certain standard bars that could be handled in the same manner as this test. That would be a guide to the treatment of simple or alloy steel castings, it being more important with the alloys than the plain steels.

This has proven to be good treatment for certain annealing heats, composed of five different open hearth heats, for four of the total of five open hearth heats, and every casting in a certain particular open-hearth heat would fail on physical test. Such a condition as this proves conclusively that the steel in this one open-hearth heat was bad before it was placed in the annealing furnace with the other four good heats, which passed a successful test of pulling a bar from each casting.

No heat treatment, no matter how well handled, will obtain certain results from poor steel, and for this reason those responsible for heat treatment of steels, should consider their profession as only complete when they have obtained a true knowledge of the melting and mechanical process through which this steel has passed. In many cases accurate melt records, properly kept and passed upon by experienced men, would reject many ingots as cast, thus saving the cost of mechanical treatment and heat treatment. This may sound impossible, but it is a fact. It is reason for the steel treater familiarizing himself with the melting and shaping of steel that he may know all of the history of the product he is handling.

RECONNOITERING IN AUTOMOTIVE CIRCLES

By V. A. Crosby

WE ARE passing through that sector of the circle of business known as "readjustments". It is quite hard to designate the beginning and end of any one of the four sectors of the circle in which our industrial life travels. The period just referred to is so closely related to the period of depression that the two may actually, in many cases, happen together; however, as a general process, hard times or depression are followed by retrenchment, lower costs, more healthy and saner business.

We are led to believe confidently that as a general average, prices are at the bed rock bottom. In some instances they are lower than wholesomely sound business principles demand. On the other hand, the automotive industry is the exception, in that it has not liquidated to the same extent that many other industries have. We are advised by an eminent economist that we have rounded the corner and are now entering that period which will tell largely who will be weeded out and who will remain as potential members of each industry.

It is obvious that the problems confronting the automotive industry as a whole, have undergone a great change during the past 18 months. From a sellers' market accompanied by rising prices, frenzied production and almost unlimited demand, we have passed to a buyers' market with its depression, falling prices, and insufficient demand in some cases to even run part time.

What readjustments can be made in the realm of production methods, designs, materials, heat treatments or methods of merchandising which will meet the changed market conditions, stimulate the demands for, and effectually increase the economic value of the automobile? These are the questions which may well engage the attention of the best minds among executives and engineers. It seems that upon the solution of such problems the future course of the automotive industry depends.

To readjust intelligently the methods of production, change designs, materials, heat treatments and many other practices with the idea in mind of lowering cost of production, thus effectually reducing the selling price of the car; it must be considered from the following standpoints:

1. Cost of such changes requiring new equipment, new layouts, new machines, etc.
2. Quality from the serviceability standpoint must not be sacrificed, however, unnecessarily high safety factors are to be discouraged.

Roger W. Babson states in a recent financial forecast that the automotive industry does not know what getting down to bed rock bottom means. This is no idle gossip when you consider the prestige Mr. Babson enjoys as an expert economist and statistician; consequently, you are not surprised that his forecasts are considered investment criterions by investment bankers and financiers.

It is hoped the automotive industry will not wait until its hands are forced, but that it may anticipate the problems to be solved and jump into the field at once. As an example we may quote a typical example of substitution:

1. Plain carbon steel for alloy steel where feasible.
2. Elimination of heat treatment where possible and practical.
3. Substitution of cast iron for aluminum, brass and bronze.

A paper presented at the January meeting of the South Bend Chapter. The author, V. A. Crosby, is foundry metallurgist, Studebaker Corp., South Bend, Ind.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

DEPTH OF PENETRATION STATEMENTS CORRECTED

CONSIDERABLE discussion has been provoked by the paper "Efficiency of Different Mixtures for Cyanide Hardening and the Role of Nitrogen in the Process" by Victor E. Hillman, metallurgist Crompton & Knowles Loom Works, Worcester, Mass., appearing on page 296 of the January issue of TRANSACTIONS. Correspondence with the author has developed that the manuscript was in error in several instances as regard to the depth of the case. With these corrected as follows, most of the questions are answered. On page 297, the last part of the fifth line from the bottom of the page should read "amounts to approximately 0.004 inch." The first part of the last line on this same page should read "to a depth of 0.007 inch." On page 298 the ordinates of the curve should read .001, .002, .003 up to .012 instead of .01 up to .12. The caption Fig. 4 on page 301 should read "Micrograph showing the appearance of the case, which is 0.0054-inch deep."

CYANIDE DATA SEEMS CONFUSING

IN TRANSACTIONS for January V. E. Hillman says on page 303 that "Various investigations have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.03 to 0.06 per cent. Under conclusions he states that "1. Cyanide hardening is poorly adapted for deep cementation."

On page 304, G. R. Brophy at the last says, in speaking of carbon per cent in the cyanide case. "We never found it as high as 0.60 per cent."

In the article by R. L. Dowell on page 320 one gains the impression that cyanide is used to cement steel to 1/16-inch depth and often much deeper and that in one instance the carbon at the center of the gear teeth was 0.75 per cent.

There have been numerous articles on cyanided work, its action, analysis of case, etc., there are however, instances such as noted above that cause confusion.

Recently one of my associates analyzed a rod taken from a cyanide basket which had been in use for at least two months. Originally this rod was mere screw stock. The carbon per cent determined was 2.74. The nitrogen was high but of course could not be compared with the original content. The material was with difficulty machined in the annealed state. The fracture was that of tool steel.

It is hoped that a solution to these varied observations may soon clear up the confusion.

STANLEY P. ROCKWELL, Metallurgical Engineer,
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FURTHER REMARKS ON CYANIDE HARDENING

DISCUSSION of paper by V. E. Hillman on Cyanide Hardening, which appeared on page 296 of the January issue of TRANSACTIONS.

Results of researches at the General Electric Co.'s research loboratories on cyanide hardening were reported before the Society in September, 1920, and were published in TRANSACTIONS in March, 1921. It was shown that nitrogen combined in some manner with iron with extreme hardness and brittleness resulting when the metal was quenched. The depth of penetration was as great after 15 minutes as was the case after one hour. Even a four hour immersion gave no appreciable increase in total depth of penetration, but it was shown that the concentration, as indicated by the amount and width of the patch layer increased with exposure. The depth of penetration was estimated by the distance from the surface to the innermost needle.

Analyses of the metal immediately on the surface of cyanided rods gave at best but 0.33 per cent carbon, not sufficient to account for the hardness obtained. The rods were of pure iron containing no carbon, so that any carbon present after treatment was introduced by the cyanide. Commercial sodium cyanide was used at a temperature of 800 degrees Cent. Under actual abrasive test cyanided parts showed but one-fifth the life of carburized parts, and when subjected to impact, failure was immediate.

In the present article the author, it appears, has not sufficient experimental evidence to support a number of his statements. His repeated assertion that cyanide exerts a carburizing action is in error, in view of his own and other investigator's results. Nitrogen is the hardener and not carbon. However, the increased carbon content of his cases and the difference in penetration may be due to the fact that his bath is made up of Na_2CO_3 plus NaCN.

When Na_2CO_3 is melted it is a well known fact that CO_2 is liberated also that NaCN is an active reducing agent. Therefore, is it not possible that CO_2 is reduced to CO with the formation of NaOCN, and the steel carburized by the CO? If this is true, then Na_2CO_3 is not inert as the author states. If this is not true, then the curves for penetration of N_2 are evidently in error in the light of recent researches. More work would have cleared these points and until that is done the statements should not be set down as truths.

The composition which the author gives for the gases above his bath is questionable as regard to Na_2CO_3 and NaCN decomposing and to NaOCN. The length of time of exposure to ammonia gas and cyanide to produce the structures seem very long. A few hours in NH_3 at 700 degrees Cent. is sufficient to produce deep cases, and from 15 to 30 minute is sufficient in cyanide.

A point of interest which the author has not mentioned is that the needle form of nitrogen has not the hardening power of the patch forms which represents a higher concentration. It is the patch area, or depth of hardness, which changes on increased exposure and not the total penetration. Diffusion of this patch zone, however, does take place to some extent on subsequent annealing and heat treatment.

The author's curves should show less penetration than other researches describe, for it is proved that increasing carbon prevents penetration and lowers concentration of nitrogen. When high carbons are used both pearlite and the nitride loose their characteristic structures, each appearing to put the other in solution.

Samples of 0.002-inch pure sheet iron were heated in NaCN for several

hours to convert them to 100 per cent nitrogen compound. These were then analyzed by the Allen method, which the author says gave good results, and practically no nitrogen was found. This would indicate that the dark patch and needle constituent are other than nitride of iron. Doctor Fay, of Massachusetts Institute of Technology, recently has been working on a method for the determination of N_2 in steel and promises some interesting data shortly.

We have shown recently that C is not necessarily present in the patch. Cases obtained by heating in pure NH_3 show this constituent, but perhaps not to the extent that it occurs in cases obtained from commercial gas. The term "Flavite" given to this patch constituent by Mr. Hillman, is a new one, not having been used in previous publications, and should be put forth as tentative until approved generally.

G. R. BROPHY, Research Metallurgical Engineer,
General Electric Co., Schenectady, N. Y.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

QUESTION NO. 7. May tools be heat treated properly in a furnace in which copper is present?

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 9. In carbonizing does not the carbon increase slightly even in the core section?

QUESTION NO. 10. What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?

QUESTION NO. 11. Has high speed steel ever been carbonized and if so what were the results?

QUESTION NO. 12. How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

QUESTION NO. 13. A swaging die for tubing receives 3600 blows per minute. It has been found that a scleroscope hardness of about 95 is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?

QUESTION NO. 14. What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.

QUESTION NO. 15. Is it possible to obtain, commercially, the following physical properties in the heat treatment of 3-inch forgings made of chrome nickel steel according to the S. A. E. specification No. 3130, selecting the test bar one-half way between the center and the outside of the forging:

Elastic limit pounds per square inch	Tensile strength pounds per square inch	Elongation per cent	Reduction of area per cent	Scleroscope hardness
115,000	140,000	17.5	63.0	40

Chemical Composition

Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent	Chrome per cent
0.25—0.35	0.50—0.80	not over		1.00—1.50	0.45—0.75
0.30 desired	0.65 desired	0.04	0.045	1.25 desired	0.60 desired

ANSWER. It is not commercially possible to obtain the above physical properties on a steel of this composition, using a 3-inch section and selecting the test bar one-half way between the center and the outside of the forging.

It would appear that in selkecting this specification from the "Physical Characteristics" chart of the S. A. E. for this steel, there has been some confusion. The figures for elongation, reduction of area and scleroscope hardness correspond to the chart for a 900 degree Fahr. drawing temperature, while the elastic limit corresponds to that for an 800 degree Fahr. drawing temperature and the tensile strength to that between an 800 and 900 degree Fahr. draw.

It is obvious that such a combination cannot ordinarily exist. Furthermore the physical properties as given in this chart have been obtained in the heat treatment of ½ to 1½-inch round specimens. Therefore they would not apply to forgings 3 inches in diameter, with the test bar selected half-way from the center to the outside. The cooling time in quenching the larger section is too great to permit the retention of the more unstable higher strength constituents.

Even the problem of obtaining these physical properties on a small sized section would be quite vexations to the heat treater. As a commercial proposition it would be even more troublesome. When the larger sections are involved it is safe to say that these properties cannot be obtained.

Unfortunately there is little information available on the physical properties which ordinarily can be obtained in the heat treatment of this class and composition of steel of a 3-inch section, with the test bar selected from midway between the center and the outside of the section. The following tabulation gives a resumè of some results obtained from various sources in the literature and it can be seen that in no case has this specification been reached, in spite of the fact that the sections have been small. Specimen No. 16 meets this specification, but is a chrome vanadium steel 1-inch in diameter.

Specimen No.	Diameter inches	Elastic limit pounds per square inch	Ultimate Strength pounds per square inch	Elongation per cent	Reduction of area per cent	Scleroscope hardness
1	1	125,000	137,000	22.0	62.0	
2	1	138,000	150,000	20.0	58.0	
3	1	160,000	178,000	17.0	53.0	
4	1	133,000	162,000	16.0	57.0	
5	1	158,000	175,000	13.0	53.0	
6	1	115,000	142,000	17.0	59.0	
7	1	150,000	165,000	18.0	55.0	
8	1	110,000	140,000	19.0	60.0	
9	1	110,000	140,000	18.0	50.0	
10	1	115,000	140,000	18.0	52.0	
11	1¼	118,000	132,000	21.5	63.0	44
12	½	120,000	141,000	17.0	57.0	42
13	1¾	121,000	138,000	21.0	60.0	40
14	1 5/16	116,000	137,000	17.0	60.0	40
15	3¾	106,000	130,000	18.0	56.0	38
16	1	123,000	141,500	18.0	63.5	

The chemical analysis of the above metals with their treatment is given below. These results were the nearest that could be found which in any way seemed to approach the specification of the oiriginal question.

Specimen No.	Carbon per cent	Manganese per cent	Chromium per cent	Nickel per cent	Quenched degrees Fahr	Drawn degrees Fahr
1	.28	.49	.63	1.79	1475	1100
2	.28	.49	.63	1.79	1475	1000
3	.28	.49	.63	1.79	1475	800
4	.37		.42	1.35	1430	900
5	.37		.42	1.35	1430	800
6	.37	.55	.42	1.35	1430	1000
7	.28	.49	.63	1.79	1475	900
8	.40		1.00	2.00	1425	1100
9	.50		.50	1.25	1425	1075
10	.40		.75	3.00	1450	1050
11	.40		70	1.31		1000
12	.40		.70	1.31		1000
13	Low nickel chrome. Exact analysis not given.					
14	.19		.90	3.50	Treatment not given.	
15	Low nickel chrome. Exact analysis not given. Treatment not given.					
16	.26	.48	.92	.20*	1650	1020

* Vanadium

QUESTION NO. 16. Does acid pickling cause brittleness in steel by widening the grain boundaries? How can pickle brittleness be removed?

ANSWER. This question was perhaps prompted by an article by C. J. Morrison, which appeared in *Iron Age* in August of this year. In this article evidence is presented which is claimed to show that the embrittling action of pickling is due to an eating out of the grain boundaries in steel. The evidence consists in three micrographs representing the following conditions: 1. Normal steel before pickling; 2. Steel made brittle by pickling; and 3. Steel made brittle by pickling and restored by heat treatment. In these micrographs the grain boundary lines appear widest in the brittle material and of less but about equal width in the other two samples. Measurements are given stating that the grain boundaries are about three times as wide in the brittle steel as in the others and it is concluded that the cause of pickle brittleness has been proved by this work.

In a later issue of *Iron Age* there is a discussion of this article by George Comstock of the Titanium Alloys Co., in which the conclusion reached in the above article is severely criticized. Comstock contends that the reason for the greater apparent width of the grain boundaries in the second micrograph is that the photograph was taken out of focus.

The writer believes that Comstock's criticism is justified inasmuch as all of the micrographs were somewhat out of focus and were poor in other respects. Pickle brittleness cannot be attributed to widening of the grain boundaries on the basis of the evidence given in this article. This does not mean necessarily that a selective attack on the grain boundary material by the pickling acid is not a factor in causing the brittleness.

It would be important to establish whether the fracture follows the grain boundaries in steel which has been made brittle by pickling. If it does not, then brittleness cannot be attributed to this cause. If it does follow the grain boundaries, brittleness can be attributed to some grain boundary condition which may or may not be a widening caused by corrosion. In looking for information on this point, I have found that most of the people

who have had experience with this difficulty have not observed the path of rupture. One metallurgist says, however, "furthermore the brittleness caused seems to be an intercrystalline one, that is, the fracture seems to follow the grain boundary."

J. V. Emmons has suggested that the brittleness may be due to a notch effect consisting in the formation by the pickle acid of minute grooves or notches on the surface of the steel especially at the grain boundaries. This would cause the metal to begin to tear at the grain boundaries. The suggestion is quite logical inasmuch as it is well known that even very light scratches on the surface of steel sheet seriously impair its cold working properties.

If the idea of surface notches is correct then the brittleness should be confined chiefly to the surface of the metal and should disappear after the surface layer is removed. There are many indications that pickle brittleness is a surface phenomenon. To begin with it is practically unnoticed except in material of small cross section chiefly sheet and wire. This may be explained in part by the fact that heavier sections such as bar stock and steel forgings are as a rule not subjected to any deforming process, which would reveal brittleness even if it exists. Steel sheet and wire are especially apt to show up this defect, because of the severe deformation they are subjected to in fabrication.

W. C. Main states that pickle brittleness can be removed by taking off a very thin layer from steel sheet, perhaps not over about 0.003 inch. This certainly indicates that the surface layers are at least the most affected, which is bound to be the case since the acid begins its attack on the surface. Opinions have also been expressed that brittleness permeates the entire cross section, especially in the case of sheets. The truth of the matter is probably that the action is similar to that of carbonizing, beginning at the surface of the metal and penetrating to a greater depth the longer the pickling is continued.

There is general agreement that this type of brittleness can be removed readily by heating and a common heat treatment seems to be about 10 hours at 400 degrees Fahr. It has also been brought out that no trouble is encountered from pickle brittleness when the metal is heated in the natural course of fabricating operations after the pickling process. This applies to material which is heated for hot rolling or annealing or which is galvanized.

The orthodox theory is that the brittleness is due to the absorption by the steel of the hydrogen liberated in the pickling process. The removal of brittleness by heating is then supposed to be due to the expulsion of hydrogen. If we accept the "notch theory" of brittleness than we must find some other explanation of the removal of brittleness by heating. Mr. Emmons has suggested that this is due to the removal of a small amount of metal by oxidation thereby rounding the corners of the notches or removing them altogether. It appears, however, that pickle brittleness can be removed by heat treatment at a temperature so low that no visible oxidation occurs, and even disappears slowly when the steel is allowed to stand or age at ordinary temperatures. This can be explained on the basis of a slow loss of absorbed hydrogen, but it is difficult to explain on the basis of removal of notches from the surface.

It is still more difficult to account for the restoration of ductility if we consider that the brittleness is due to the actual removal of grain boundary

metal. The most that we can concede the grain boundary theory is that the grain boundaries are particularly affected either because of a local penetration of hydrogen or because of the notch effect mentioned.

In connection with this question the writer has made some inquiries as to the prevalence of pickle brittleness and found that the largest producers of material in which this defect might be expected do not seem to have much trouble with it. One large company reports that much of its product is not heat treated subsequent to pickling and is subjected to severe deforming operations by customers without any difficulty. It is to be expected that the effect of the brittleness developed will depend considerably on the pickling conditions. Some alternating bend tests by Prof. H. O. Arnold on steel bars showed that doubling and trebling the time of pickling continuously decreased the toughness of the steel. It seems, therefore, that if proper care in pickling is exercised and especially if some time elapses between pickling and use, brittleness is the exception rather than the rule.

QUESTION NO. 17. *For some time past we have been water quenching steel castings in order to improve their physical properties. These castings are mostly shrouded pinions and plain rollers, weighing from* 150 *to* 500 *pounds each. These pieces would be immersed in the water bath for a short period of time, usually from one to two minutes and then withdrawn and allowed to cool in the air. Our results have been satisfactory but we feel that we can improve this method somewhat by a slight modification in the treatment. In order to relieve cooling strains, one suggestion is that we provide a tank filled with infusorial earth in which the castings would be placed in order that cooling might be slow and uniform. Another suggestion is that instead of using a plain water bath, we introduce sodium hydrate in order that the quenching may not be quite so severe. We would like to know which of the above plans would be the better or if there is any other better plan which could be suggested. We do not care to use oil because of its expense.*

NOTE. Rollers may break in the flange a month or more after above treatment. Loss at present is 2 *per cent. Pinions, after above treatment, are drawn in furnace to* 1200 *degrees Fahr. for toughness. If drawn shortly after quenching there is no trouble, but this is not always practicable when working day turn only. If allowed to stand in air after quenching, cracking may result, hence the suggestion for covering with infusorial earth or ashes. We have had only one batch to show cracks.*

QUESTION NO. 18. *What is the relationship between Brinell and Scleroscope hardness?*

QUESTION NO. 19. *What is the shortest time in which malleable castings can be annealed to produce the best malleable qualities?*

QUESTION NO. 20. *What are the causes of warping in the heating and cooling of steel?*

QUESTION NO. 21. *In answering Question No.* 3, *which appeared in the January issue of* TRANSACTIONS, *C. Craine, Mattison Machine Works, Rockford, Ill., refers to the fact that cast iron gage bases were treated at temperature from* 600 *to* 900 *degrees Fahr. for a period of* 12 *to* 18 *hours, and were allowed to cool in the furnace, the theory being that this treatment*

obviated the necessity for the ageing of the castings. What effect, if any, would have been produced had the castings been heated to a very much higher temperature, say 1600 *degrees Fahr.? In view of the fact that certain of the castings referred to had to be twice re-treated in a similar manner for* 12 *to* 24 *hours, before overcoming all effects of warpage, the value of the treatment seems doubtful. What assurance is there that some of the castings which were treated but once, ought not to have been treated twice, or even three times?*

ANSWER. By H. A. Schwartz, manager of research, National Malleable Castings Co., Cleveland. Any casting develops internal stresses due to unequal cooling and retains its final shape due to a balance between opposing internal stresses. On machining off stresses material, the equilibrium is disturbed and the casting warps. Ageing, heating, vibration or the removal of metal with light cuts on opposite sides all serve as a means of slowly relieving internal stresses and hence of preventing warping on subsequent machining. It would seem that to be effective as an eliminator of casting strains, the temperature reached in heat treating must be sufficiently high to cause a distinct increase in ductility of the iron. Such an increase is not observed until the metal is heated above 900 degrees Fahr., but the increase in softness with increasing temperature above 900 degrees Fahr. is very rapid. Any temperature above 1400 degrees Fahr. if maintained sufficiently long will cause a resolution of the graphite with possible increase of hardness unless cooling is very slow. At temperatures as high as 1600 degrees Fahr. the metal, if it contains graphite, must be protected from oxygen, or carbon dioxide, else these gases will oxidize carbon, penetrate into the metal first where the graphite was and later along the grain boundaries, oxidize the metal and produce a "rotten" product. In any event the cooling of the metal must be uniform throughout and quite slow.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest
to Metallurgists and Heat Treaters

By H. E. Gladhill

CHROME STEEL

CHROMIUM STEELS AND IRON. By Leslie Aitchison, *Engineering,* Vol. CXII, Pages 771 and 805.

The properties required of an alloy steel for use in automobile parts are described and it is shown that chromium steels fulfill the requirements in a fair measure. Three per cent chromium is recommended for heavy work while 1 to 1.5 per cent is sufficient for small parts. The proportion of carbon in the steel exercises a greater influence than does the chromium on the physical properties. Stainless irons are recommended for their ease in working. Vanadium is not found to benefit chromium steels.

FORGING AND HEAT TREATING EXPERIMENTS

FORGING EXPERIMENTS WITH MILD STEEL. By P. J. Junkers, *Forging and Heat Treating,* Vol. 7, Pages 518 and 553.

Tests were made on 0.13 and 0.50 per cent carbon steels. Forging the 0.13 per cent carbon steel below 750 degrees Cent. raised the breaking strength and elastic limit. Forging above 750 degrees Cent. lowered these properties. With the 0.50 per cent carbon steel, the improvment in properties due to forging was greater than in the case of the 0.13 per cent carbon steel. Photomicrographs illustrating the effect of forging on structure are shown.

ON THE HEAT TREATMENT OF ALUMINUM BRONZE. By A. A. Blue, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1043.

Marked changes in the hardness of the 90 per cent copper, 10 per cent aluminum alloy may be produced by heat treatment. The tensile strength and yield point, however, are little affected by heat treatment or by forging. Difficulty is encountered in obtaining uniform results with the cast alloy. Published data on the physical properties is not duplicated under practical working conditions.

INFLUENCE OF PHOSPHORUS UPON MICROSTRUCTURE AND HARDNESS OF LOW CARBON STEELS. By E. C. Groesbeck, Bureau of Standards, Technologic Paper No. 203.

Heat treatments were run on acid and basic open-hearth, low carbon steels containing varying amounts of phosphorus. The Brinell hardness was found to increase slightly with increase in phosphorus. No relationships were found between phosphorus content and grain size and phosphorus content and scleroscope hardness. A peculiar cellular-like structure was noticed and its relation to the phosphorus distribution established.

HIGH SPEED AND CARBON TOOL STEEL

HARDNESS OF HIGH SPEED STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1168.

Experiments made on 15 samples showed that so far as uniform structure and good cutting properties are concerned the best heat treatment for high speed steel was quenching in oil from 2300 degrees Fahr. and drawing 1100 degrees Fahr. Quenching the steel into a bath at 1100 degrees Fahr. and air cooling without drawing did not give the same good results as were obtained by drawing the quenched tool at 1100 degrees Fahr. High speed steel in large rounds is seldom free from carbide and tungstide segregation. Tools made of this material were inferior to those made from material having been given a greater reduction in cross section.

Neither scleroscope nor Brinell hardness were found to be indicators of cutting quality.

VARIOUS METHODS FOR HARDENING HIGH SPEED STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1150.

Salt and lead bath hardening, pack hardening and semimuffle furnace hardening are described and their advantages and disadvantages discussed. The first three reduce the amount of scaling but in general give too low a quenching temperature for best results. The last method is the one most used in this country.

AMERICAN PRACTICE IN HIGH SPEED STEEL MANUFACTURE. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1097.

The information contained in this article was obtained as a result of visits to eight of the largest tool steel mills in the country. Crucible practice was used at six of the mills, the electric furnace being used for melting at the two remaining plants. In general, muck bar is used as a base for high speed steel. Considerable diversity of opinion exists as to the proper materials for fluxing, etc., in electric furnace practice. "Hot top" casting practice generally is used. The ingots are hammered into billets and the billets are reduced by rolling or hammering. Photomicrographs are shown of the steel at the various stages.

NOTE ON MUSKET STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1055.

Three heat treatments were made on samples of musket steel. The steel contained 2.38 per cent carbon, 1.12 per cent chromium and 4.80 per cent tungsten. Quenching from 1900 degrees Fahr. and drawing at 1000 degrees Fahr. give the best structure.

HEAT TREATING OF TOOL STEELS. By L. A. Lanning, *Blast Furnace and Steel Plant,* Vol. 9, Page 706.

The tests were made on 1.10 per cent carbon tool steel in the form of cylinders. The effect on dimensional changes of various heating up rates, hardening temperatures, quenching media and tempering temperatures was determined. The data is presented as curves.

METALLOGRAPHY AND HARDNESS THEORY

PRESENT THEORIES OF CARBURIZING STEELS. By H. B. Knowlton, *Forging and Heat Treating,* Vol. 7, Page 543.

The iron-carbon diagram is explained and the carbonizing reaction is described. The effect of single and double heat treatments on carbon distribution, grain size and hardness is discussed and illustrated by numerous photomicrographs.

ON THE THEORY OF THE HARDENING OF METALS. By K. Honda. *Chemical and Metallurgical Engineering,* Vol. 25, Page 1001.

The "slip interference" theory of Jeffries and Archer is discussed. Honda considers hardness to be due in part to interatomic forces and in part to an interlocked crystal structure.

STRAIN LINES IN LOW CARBON STEEL. By A. Fry, *Iron Age,* Vol. 108, Page 1401.

The use of a macroscopic etching reagent consisting of, water 100 cubic centimeters, concentrated hydrochloric acid 120 cubic centimeters and copper chloride crystals 90 grams is described. The sample of steel must be given a short low temperature anneal before it is affected by the reagent. Strained low carbon steel is the only ferrous product the reagent has given results on thus far.

ACTION OF INTERNAL STRESS ON TOOL STEEL. By C. N. Greenwood, *Forging and Heat Treating,* Vol. 7, Page 560.

The possible origin of initial stresses in metals and alloys are examined. Cold working and suppression of phase changes are the two main causes. The later factor is developed in some detail. Manganese and chromium are recommended for reducing strains due to quenching. No new data is presented.

ELEMENTS OF THE HEAT TREATMENT OF STEEL. By H. J. French, *American Machinist,* Vol. 55, Pages 907 and 960.

Heat treatment is classified as being made up of the following operations: (1) Normalizing and annealing, (2) hardening, (3) tempering, (4) seasoning and (5) case hardening. The structural and physical property changes brought about by these operations are described and illustrated by photomicrographs, curves and tables of data.

PHYSICAL TESTS

PHYSICAL TESTING LABORATORIES DESCRIBED. By G. F. Comstock, *Forging and Heat Treating,* Vol. 7, Page 549.

A plan, view and brief description of the Titanium Alloy Mfg. Co.'s laboratory is given. The laboratory is housed in a long, narrow, well-lighted brick building.

SCLEROSCOPE HARDNESS OF STEEL BALLS. By A. L. Collins, *Iron Age.* Vol. 108, Page 1391.

With a series of balls held in the usual way on the anvil of a scleroscope, readings which are very apparently incorrect are obtained. Experiments showed that the difference in the curvature was not responsible for the irregularities. Imbedding the balls in soft solder in blocks of special design eliminated the difficulties giving uniform readings for all sizes of balls.

OXIDES AND SULFIDES IN ORDNANCE STEEL. By W. J. Priestly, to be presented at the February, 1922 meeting of the Institute of Mining and Metallurgical Engineers.

It is shown by photomicrographs, analyses, and physical tests that properly made duplex electric steel is superior to straight open-hearth steel. Methods of steel production in the various ordnance plants during the war are discussed.

ENDURANCE OF STEEL UNDER REPEATED STRESSES. By D. J. McAdam Jr., *Chemical and Metallurgical Engineering,* Vol. 25, Page 1081.

Data from a very extensive series of tests is presented in an endeavor to correlate endurance stresses with other physical properties. The endurance tests were made on a modified White-Souther machine. Carbon steels running from 0.13 to 0.77 per cent carbon as well as 14 of the common alloy steels were tested. Curves of endurance test results on logarithmic or semilogarithmic paper showed no abrupt change of direction throughout the cycle range investigated. No relationship between endurance stress for 100,000,000 cycles and the corresponding proportional limit was found. A relationship does not exist, however, with the ultimate tensile stress. The ratio of endurance stress to Brinell hardness and to maximum torsional stress were found to be quite uniform. No relationship was found between the results of impact tests and endurance tests.

WELDING AND CUTTING

EFFECT OF OXYHYDROGEN CUTTING ON LOCOMOTIVE RODS. By A. F. Pitkin, *American Machinist,* Vol. 55, Page 964.

Blocks were cut from slab forgings, used for locomotive main rod forgings. Chemical analysis and metallographic inspection showed the heating effect of the cutting to be negligible on the remainder of the cut forging.

STEEL PLANT MAINTENANCE BY AUTOGENOUS WELDING. By Walter Petry, *Association of Iron and Steel Electrical Engineers,* Vol. 3, Page 555.

Important points and new developments in the use of the thermit, acetylene and electric arc welding processes are given. The thermit weld is in general better for heavy sections. For thin sections of cast iron gas welding generally is best. Most steel welds are best made by the electric arc processes. Examples of the use of welding methods in the steel mill are given.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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PUSITZ, L.—from 5348 Russell, to 3514 28th St., Detroit, Mich.
RODNEY, KEITH R.—from Bullard Machine Tool Co., Bridgeport, Conn., to New Castle, Delaware.
ROWE, CHAS. O.—From Electric Alloy Steel Co., 511 Penna. Bldg., Philadelphia, Pa., to 330 W. Duval St., Germantown, Philadelphia, Pa.
SCOVEL, ALFRED J.—from D. O. James Mfg. Co., 1120 W. Monroe St., Chicago, Ill., to 5912 Grand River Ave., Detroit, Mich.
SIMMONS, C. P.—from Latrobe Elec. Steel Co., 165 Broadway, to 366 Madison Ave., New York City.
SHAW, G. M.—from 642 Munsey Bldg., Washington, D. C., to 1517 Continental Bldg., Baltimore, Md.
TORSELL, CARL T.—from The Warren Iron and Steel Co., Warren, Ohio, to 112 Dickey Ave., Warren, Ohio.
WEDLAKE, PERCY—from Washington Steel & Ordnance Co., Washington, D. C., to 125 Atlantic St., R. F. D. No. 8, Anacostia, D. C.
WESLEY, CHAS.—from 651 S. Pierce St., to 348 13th Ave., Milwaukee, Wis.
WHITE, W. H.—from Box 296 to 3 Washington St., S. Charleston, W. Va.
WILLIAMS, W. E.—from 3317 Rhodes Ave., Armour Sta., Chicago, Ill., to 504 Oakwood Blvd., Chicago, Ill.

MAIL RETURNED

BONNER, WM. T., Engr., New York Shipbuilding Corp., Camden, N. J.
EVES, ROBT. J., Erie Beach, Ont., Canada.
GEBERT, N. J., 717 W. Genesee St., Syracuse, N. Y.
GUSTAFSON, R., 1815 13th Ave., Moline, Ill.
PENROD, W. W., 1664 Waterbury Rd., Lakewood, Ohio.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Engineering Societies building, 29 West Thirty-ninth street.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri Cities—First Thursday following first Monday.

Washington—Second Friday.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held its postponed December meeting on Friday night, Jan. 6 at the Engineers Club. The speakers of the evening were Horace Drever, and Dr. W. M. Mitchell. Mr. Drever, who is engineer for the Electric Furnace Construction Co., presented an illustrated lecture on "Typical Electric Heat Treating Furnaces." This lecture was very interesting and was well received.

A new and important feature of the meeting was the illustrated talk by Dr. W. M. Mitchell on "The Crystalline Structure of Steel." This was the first of a series of short talks on the fundamentals of the heat treating art which will be given at each meeting for the benefit of the general membership. These talks will be very practical, not highly theoretical and are intended to explain and make clear to the ordinary every day users, the terms, methods an processes in common use. No one engaged in the treating of steel can afford to miss these practical talks, and Dr. Mitchell's paper created considerable discussion, and proved mutually beneficial to all.

The January meeting of the Philadelphia Chapter was held in the Engineer's Building on Jan. 27. H. J. Stagg, assistant manager of the Halcomb Steel Co., Syracuse, N. Y., addressed the chapter. Mr. Stagg's illustrated talk was one of the best that has been presented before the local chapter this year, and carried with it the valuable experience Mr. Stagg had while metallurgist for the Halcomb Steel Company before his promotion to assistant manager. Mr. Stagg's pleasing personality, his wide circle of acquaintances, as well as the high regard in which he is held as a metallurgist all contributed in making the meeting a notable success.

The second of the series of fundamental talks was given by Edwin H. Barker, of the A. H. Wirz & Co., Chester, Pa., on "Local Hardening of

Extruding Dies." Mr. Barker's paper was illustrated with lantern slides and proved to be very interesting and was exceptionally well received.

The local chapter is having a membership campaign which closes on the night of the annual meeting to be held on Feb. 24. Last year the annual meeting was one of the largest held by any of the local chapters, and the claim is put forth that this year's meeting will be larger and better than the last. The list of invited guests is quite imposing and it is expected that the entire membership will be represented and bring with them the new members they have secured during the drive. National President Gilligan will be present at that meeting and the chapter is anxious to prove to him that they still retain the pep they previously had, and that they have thoroughly disproved the idea held in some quarters that Philadelphia was asleep.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held the third meeting of its series on the "Manufacture, Treating and Testing of Steel." George C. Lilly, superintendent of the treatment department, Bethlehem Steel Co., and a member of the excutive board of the Chapter, was the speaker at a meeting of the Lehigh Valley Chapter held in the Auditorium of the Easton Public Library, Jan. 9. Mr. Lilly gave an illustrated talk on "Heat Treatment."

This was the third meeting of the series of practical and elementary talks which the Chapter is conducting on the manufacture, treating and testing of steel. As announced in the January TRANSACTIONS, this meeting was to have embraced "Rolling Mill and Foundry Practice" but the committee was obliged to change its plans and Mr. Lilly, who was scheduled to talk at a later date, very graciously met the emergency.

Mr. Lilly's talk was a thoroughly practical one throughout. Fully 75 charts, diagrams and photographs were used to illustrate the many phases of the practical application of heat treatment. Mr. Lilly's practical interpretation of the theory of and the terms used in defining heat treatment was considered by those present to be the clearest and simplest which had ever been presented to them.

The results of many tests were shown giving the effects of different heat treatments upon the physical qualities of steel. Mr. Lilly spoke at considerable length on the factors affecting the quality of heat treated product, such as the influence of the forging operation, the time allotted for heating both for forging and treating, the effect of mass on the physical properties, etc. Mr. Lilly also illustrated and discussed some of the equipment such as various types of furnaces and quenching apparatus used in the application of heat treatment of large forgings. The talk throughout was true to the form of the series and gave those attending the meeting much valuable information which they could apply in their every day practice.

WASHINGTON CHAPTER

The January meeting of the Washington Chapter was held on Friday, Jan. 20 in the ball room of the Harrington Hotel. The paper of the evening was by T. Holland Nelson, steel works manager of the Henry Disston & Sons Co., Philadelphia, Pa. Mr. Nelson's subject was a comparison of American and English methods of producing high grade crucible steels.

High grade tool steel demands the greatest skill, experience and precise knowledge for its proper manufacture. The position of Sheffield in the history and development of steel is known wherever tool steel is used. By reason of his experience in America and abroad, the speaker was particularly

fitted to contrast the methods of producing crucible steel in the Sheffield district with that produced by the best American practice. A comparison of the English product, made in the clay pot in coke hole furnaces, with the Amerian product, made in the graphite crucible in regenerative gas furnaces, showed many striking differences. Interesting details of the materials used and compositions made were brought forth. The meeting was largely attended and proved of much interest.

CINCINNATI CHAPTER

The Cincinnati Chapter held its regular January meeting on Monday, Jan. 23 at the R. K. LeBlond Machine Tool Co.'s plant. President F. P. Gilligan was present and after an interesting talk on society affairs, presented a paper illustrated with lantern slides on the subject of "What Happens to Steel When You Quench It." This was the first opportunity many of the members had to become acquainted with Mr. Gilligan, and a very excellent turn-out greeted the president

SOUTH BEND CHAPTER

The December meeting of the South Bend Chapter was held on Dec. 13, in the Recreation Building of the Studebaker Corp. Cider, doughnuts, cigars and cigarettes were served. About 55 attended the meeting.

The meeting took the form of a general discussion. Slips of paper were passed to each person on which they were to write a question to be brought before the meeting. These were then read and a discussion followed. The questions produced a great deal of discussion which had to be limited to 15 minutes for each question. At the end of the discussion V. A. Crosby, metallurgist at the Studebaker foundry, read a short paper on "Reconnoitering in Automotive Circles."

One of the best meetings the South Bend Chapter has held for some time, considered from the point of interest, and discussion took place on Jan. 10 at the Y. M. C. A. building. William Finkl, of A. Finkl & Sons, Chicago, was the speaker of the evening, selecting the subject of "Die Blocks." He handled his paper in a most capable manner. The discussion lasted for two hours after Mr. Finkl had finished the presentation of his paper.

The next meeting will be held on Feb. 14 and will be addressed by President Gilligan.

HARTFORD CHAPTER

The February meeting of the Hartford Chapter was held in Jewell Hall on Thursday, Feb. 9. The principal paper was presented by A. H. d'Arcambal, metallurgist of Pratt & Whitney Co. Mr. d'Arcambal has made extensive investigations of the effects of variations in composition and heat treatment on the life of high speed steel cutting tools. These investigations were conducted for the purpose of determining the best composition and best heat treatment to be used for tools manufactured by the Pratt & Whitney Co. His talk was illustrated by lantern slides, and was very instructive.

At this meeting, specimens were distributed, to be heat treated for the March Contest Meeting.

Particular attention is being given at the present time to arrangements for the plant visitation on April 29 at the New Departure Co., Bristol, Conn. This meeting has been arranged through the courtesy of the Bristol company, and will consist of the inspection of the entire

manufacturing plant. The inspection will start a 9 a. m. and dinner will be served at the New Departure plant at noon, and the afternoon will be devoted to talks.

This meeting has been arranged through the efforts of the local chapter and will be considered as a joint meeting of engineering societies, under the auspices of the American Society for Steel Treating and the Hartford and New Britain Sections of the American Society of Mechanical Engineers. It is expected that all of the New England sections of the above societies will be represented.

The Heat Treating plant of the New Departure plant is as large and up-to-date as any plant in the New England section and the chapter is looking forward to this meeting being one of the most interesting as well as the most instructive that they have ever held.

The list of meetings for the remainder of the season is as follows:

MARCH 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.

APRIL 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Mathews, President Crucible Steel Co., Pittsburgh.

APRIL 29:—9:00 a. m., Inspection of New Departure Co. Plant, Bristol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.

MAY 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.

JUNE 8:—Annual Banquet. Speakers to be announced later.

In addition to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

SCHENECTADY CHAPTER

The December meeting was held on Dec. 20 at the regular meeting place, the Civil Engineering building, Union College. A paper was presented by W. E. Ruder, metallurgist, General Electric Co., on the subject of "Fatigue of Iron and Steel." About 55 members and guests were present, and enjoyed Mr. Ruder's presentation of this subject very much, and they also participated actively in the discussion. Special singing and moving pictures served as the entertainment of the evening.

The January meeting was held on the 17th when President Gilligan paid his annual visit to the chapter and presented a very interesting paper. Secretary Eisenman was also present and gave a few remarks with reference to the progress of the National Society. Moving pictures, through the courtesy of the General Electric Co. were also shown.

The Schenectady Chapter has issued a very fine little folder giving the dates and subjects of their meetings throughout the year, as well as a list of their chapter officers and the executive committee.

NEW HAVEN CHAPTER

The regular monthly meeting of the New Haven Chapter was held on Wednesday evening, Jan. 25 at the Hammond Laboratory, Yale University. This consisted of the inspection of the excellent equipment of the laboratory as well as a few short practical talks.

Much interest is being aroused by the prospect of a night course in metallurgy to be given at Yale University during the coming fall and winter, under the auspices of the Hammond Laboratory and with the cooperation of the New Haven Chapter. Professors Mathewson and Phil-

lips of Yale are working on the course in co-operation with the following committee appointed from the chapter: Fred Dawless, Chairman; members: Major A. E. Bellis, Walter Aurand, James Black and James Dunlevy.

TRI CITY CHAPTER

One of the best meetings the chapter has held for some time was that in honor of the official visit of National President Gilligan. Quite a large number attended the dinner held in the Davenport Chamber of Commerce on Jan. 26. In addition to President Gilligan's illustrated talk, motion pictures showing the manufacture of steel for sheets and plates were given through the courtesy of the Bureau of Mines.

CHICAGO CHAPTER

The January meeting of the Chicago Chapter was held at the City Club on Jan. 11 when over 100 members and guests participated in a practical discussion upon a number of very interesting subjects. Many of the questions brought up are published in the Question Box in another section of this issue of TRANSACTIONS. President Gilligan will be the speaker for the February meeting to be held at the City Club on the 9th.

The following announcement issued by the Lewis Institute is of special interest to members of the Society.

The department of mechanical engineering of Lewis Institute announces the following evening courses covering subjects of interest to members of the Society. Applications should be filed at once, preferably by Feb. 1. Applications received after the quota has been filled will be placed on the waiting list. Sessions begin on Monday and Tuesday, Feb. 6 and 7, and continue, two evenings per week, for 15 weeks.

3B-Heat Treatment of Steel—A lecture and shop practice course embracing:

A study of the iron-carbon diagram; the effect of heat and work on the crystalline structure of steel; methods of selecting different grades of steel; methods of measuring temperatures and of calibrating pyrometers; critical temperature and how determined; theory of forging and effect of improper methods; purpose of annealing; hardening, grain refining, quenching, tempering, drawing; methods of case hardening; causes of warping and cracking of hardened steel pieces; testing for hardness and other physical properties; treatment of high speed and other alloy steels; discussion of various problems met in daily practice by heat treaters, shop foremen, steel salesmen, etc. Monday and Wednesday evening. First session, Monday, Feb. 6, 6:20 to 9:40 p. m. Tuition $20.00.

3E Metallurgy of Iron and Steel—A lecture course in descriptive metallurgy intended, primarily, for the nontechnical men in the iron and steel industry who desire to know the "why and wherefore" of the materials with which they work. A general study will be made of the blast furnace, bessemer, open hearth, electric furnace, puddling, and crucible processes. This should make it clear why one kind of steel is better than another for a given purpose. A survey will be made also of the operation of rolling mills, forge plants, and foundries. The last mentioned will include a brief study of cupola operation and molding-embracing the production of gray, white, and malleable cast irons. A study will be made of the various defects in steels and cast irons, including their causes, methods of detection, possibility of elimination, and their bearing on the physical properties of finished products. The entire subject will be viewed from the standpoint of the engineer and user of iron and steel. Monday and Wednesday evening. First session, Monday Feb. 6, 6:20 to 8 p. m. Tuition $10.00.

3D Metallography of Iron and Steel—A course in the preparation and microscopic examination of variously treated specimens of low and medium carbon steels, tool steel, high speed, and other alloy steels, wrought iron, and the various cast irons. Students prepare their own samples for examination employing the methods used in commercial laboratory practice. They make photomicrographs of many of their

specimens. A student satisfactorily completing this course should be able to interpret photomicrographs, and correctly diagnose a defective piece of steel. Lectures follow Sauveur's *Metallography of Iron and Steel.* Tuesday and Thursday evening. First session, Tuesday Feb. 7. 6:20 to 9:40 p. m. Tuition $20.00.

BUFFALO CHAPTER

The Buffalo Chapter held its regular January meeting on Jan. 17 at the Genesee hotel. Prof. D. W. Wilson of the Massachusetts Institute of Technology was to have presented a paper on the "Principle of Basic Open-Hearth Steel Making", but was unavoidably detained and could not be present, however the meeting was turned into a general discussion meeting led by Chairman Blocksidge and proved to be very interesting. A number of very important subjects were considered and discussed.

The February meeting will be addressed by President Gilligan and will be held on Wednesday, Feb. 15.

MILWAUKEE CHAPTER

On Tuesday, Jan. 24, at the Medford hotel, the Milwaukee Chapter held its regular monthly meeting. The speaker of the evening was National President Frank P. Gilligan, of the Henry Souther Engineering Co., Hartford, Conn., who presented a very interesting paper on "Material and Workmanship".

President Gilligan also presented various items of interest showing the activities of the National Society. His visit was thoroughly enjoyed.

PROVIDENCE CHAPTER

The January meeting of the Rhode Island Chapter Jan. 4 was addressed by Stanley P. Rockwell, metallurgical engineer on the subject of "Carburizing". The talk was illustrated.

Mr. Rockwell's experience as metallurgist with the New Departure Mfg. Co. and his further experience as consulting metallurgist, particularly qualified him to speak on this subject which included: carburizing materials; steels and their selection; impurities in steel affecting heat treatment; soft spots from carburizing, hardening, grinding and testing.

ROCHESTER CHAPTER

The Rochester Chapter held its January meeting on Wednesday, Jan. 11 at the Rochester Engineering Society rooms. The speaker of the evening was George Berry, chief chemist of the Halcomb Steel Co., Syracuse, N. Y., who selected as his subject "From Ore to Steel". His paper was illustrated and was of particular interest to all users of steel. A large number was in attendance.

DETROIT CHAPTER

The second December meeting of the Detroit Chapter was held at the Board of Commerce on Thursday, Dec. 29, and was addressed by Judge Pliney W. Marsh on "Things of Interest to Detroit Citizens". Judge Marsh had a thorough knowledge of the things that would interest Detroit citizens and his talk held the closest attention during its presentation.

The first January meeting was held on Monday, Jan. 9, at the Detroit Board of Commerce. The first meeting of the new year proved to be decidedly successful and a very interesting paper was presented by W. G. Calkins, metallurgist for the Detroit Twist Drill Co. Mr. Calkins' subject, "Forged High Speed Milling Cutters", was handled in

such a capable manner and proved so instructive to the tool men, designers, hardeners, and makers who were present that a considerable amount of discussion followed.

The second January meeting was held on Monday, Jan. 23, and was addressed by Henry Traphagan, consulting metallurgist of the Toledo Steel Castings Co., whose subject was "Fatigue of Steel". The notice of the meeting also contained the following note of interest to the membership:

"A class in elementary metallurgy will begin on Tuesday, Jan. 31, at Cass Technical high school, continuing every Tuesday evening from 7:30 to 9 o'clock, to consist of lectures and recitations, lasting until the middle of June. Register January 30 or 31 in the school annex, corner Second and High Street."

NEW YORK CHAPTER

The general meeting of the New York Chapter was held at the Engineering Society's building on Wednesday Jan. 18 at 8:00 p. m. Arthur W. F. Green, chief of the laboratory of the John Illingworth Steel Co., Philadelphia, presented an illustrated lecture on "The Annealing and Treating of Tool Steels." Mr. Green presented a very capable and instructive paper, and all those present were strong in their praises of the excellent manner in which Mr. Green had handled the subject.

The practical talks for the remainder of the season are as follows:

FEBRUARY:—Case hardening (carburizing and subsequent heat treatment) Ways of doing it, and what it does to a piece of steel.
MARCH:—Sectional Meeting, Friday, March 3.
APRIL:—Treatment of high speed steel.
MAY:—Hardening room troubles, shrinkage, warpage, scaling.
JUNE:—Spotting the reason for failures in service. Practical uses for microscopes and physical testing machines.
Added Attraction:—Current events, a 10-minute talk at each meeting on recently published items of interest to heat treaters. Come to the meetings and get into the discussions of the topic presented.

CLEVELAND CHAPTER

The Cleveland Chapter held its regular monthly meeting at the Cleveland Engineering Society's rooms, Hotel Winton, Friday evening, Jan. 27. The paper for this meeting was presented by W. R. Chapin, director of testing department of the E. C. Atkins & Co. of Indianapolis. The title of his paper was "Properties of Some Steels in the Hardening Range". Mr. Chapin is a very capable metallurgist and a very pleasing speaker and had a real message for the large number in attendance. Dinner was served at 6:30.

C. G. Shontz, chairman of the Cleveland Chapter, taught the January class in metallography in the Cleveland School of Technology of the Y. M. C. A. Mr. Shontz taught some classes on heat treating last semester and met with great success.

SPRINGFIELD CHAPTER

The Springfield Chapter held its regular January meeting on Friday, Jan. 27 at the auditorium of the Chamber of Commerce. The speaker of the evening was Walter F. Graham, metallurgist of the Henry Souther Engineering Co., Hartford, Conn. Mr. Graham's lecture was illustrated with lantern slides, and was presented on the following subject, "The Variation

in Hardness of Hardened Steel." The attendance was very satisfactory and all present enjoyed Mr. Graham's talk. Arrangements have been made for a visitation to the government arsenal, Saturday afternoon, Feb. 24.

NORTH WEST CHAPTER

The regular meeting of the North West Chapter was held Wednesday evening, Jan. 18 at the Manufacturers' Club. Dinner was served as usual at 6:30, and the business meeting commenced at 7:30. The program committee was very fortunate in arranging an interesting evening. Three reels of motion pictures were exhibited. These pictures were produced by the Commonwealth Steel Company of St. Louis, Mo., and showed the methods of manufacturing open-hearth cast steel devices used in the construction of locomotives and cars. The pictures were explained by members of the Executive Committee who very gladly answered many questions that were asked at the close of the meeting.

SYRACUSE CHAPTER

The monthly meeting of the Syracuse Chapter was held on Jan. 6 in the auditorium of the Chamber of Commerce. Due to unforeseen circumstances, the regular speaker of the evening was unable to be present and consequently H. J. Stagg, chairman of the local chapter, substituted. Mr. Stagg's paper was unusual in that its scope was wide and he did not dwell too much on theory but quoted directly from experience with actual conditions. His fervid battle cry of "Heat slowly and uniformly, quench in suitable medium and draw immediately" will remain for some time with his hearers. About 100 attended the meeting.

INDIANAPOLIS CHAPTER

The January meeting was held on Jan. 10 at the Chamber of Commerce where a very interesting meeting took place. Moving pictures were shown. The question box was made a very important portion of the meeting and an elaborate discussion was participated in by the large number in attendance. W. R. Chapin, metallurgist E. C. Atkins & Co., will be the speaker at the chapter meeting on Feb. 6.

BOSTON CHAPTER

The Boston Chapter January meeting was held on Friday evening, Jan. 20. Stanley P. Rockwell, consulting metallurgist of Hartford, presented a very interesting paper upon the subject of "Carburizing". Mr. Rockwell was true to his previous reputation of being a first-class speaker and of having a fund of information upon this subject. The amount of discussion secured was very large and proved to be exceedingly profitable.

ST. LOUIS CHAPTER

The St. Louis Chapter held its regular meeting at the Engineer's Club at 8:00 p. m. on Friday, Jan. 20. The meeting was designated as a practical meeting, and was addressed by G. S. Rogers of the E. F. Houghton Co., on "Case Hardening," and C. B. Swander of the Wagner Electric Mfg. Co. on the subject of "Quick Tests." The meeting was very well attended and especially interesting. Quite a number of questions were presented and answered.

CHARLESTON CHAPTER

One of the best meetings the Charleston Chapter has had for some time was held on Thursday, Jan. 19, at the Kanawah Hotel. President Gilligan paid his first visit to the chapter and was greeted by a very

large attendance of members and their friends who enjoyed immensely the opportunity of meeting the National President. C. A. Gosztonyi presented an interesting paper on "Forging Practice" at the same meeting.

Lt. Col. A. E. White, past president of the National Society, will be the speaker at the meeting on March 7. His paper probably will be on the subject of "top discard" which will be of special interest to the United States Naval Ordnance Plant.

ROCKFORD CHAPTER

At a recent meeting of the Rockford, Ill., chapter, Otto F. Muehlemeyer, metallurgist of the Barber-Colman Co., Rockford, Ill., presented an exhaustive paper on the hardening of steel.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, March, 1922 No. 6

TRANSACTIONS ADDS ANOTHER NEW FEATURE

IN THE February issue of TRANSACTIONS appeared for the first time a new department, "Comment and Discussion." That the inauguration of this feature was an improvement to the publication is not questioned, a need for such a column having been felt for some time. Depending upon the support received from Society members and friends, "Comment and Discussion" will appear in every issue of TRANSACTIONS and an attempt will be made to extend its usefulness.

This department is open to general participation, its function being primarily for the discussion and criticism of the articles published in TRANSACTIONS, however, its field is not limited to that alone. Any subject of interest to the Society and its welfare and worthy of comment in a brief way properly comes within the scope of this column. The February and March issues give examples of what can be done in discussing the technical articles. In the interest of greater service, it is hoped the new department will receive active support.

EARLY DISCOVERY OF THE RECALESCENCE POINT IN HEATING STEEL

FOLLOWING is an interesting item concerning the first observation of the recalescence point in the heating of steel. The item is reprinted from a recent issue of *Machinery*.

"In a publication issued in 1778 by one of the industrial associations of that time in Sweden, there is an article on the hardening of steel, written by J. F. Angerstein, in which the author mentions that he has observed a means whereby the correct hardening temperature for steel may be accurately determined. He points out that at the right hardening temperature there is a sudden shadow or lack of brightness in the object being heated. This shadow is evidently caused by the temperature reduction which takes place when the steel passes the recalescence point. It was not possible for the early observer to understand the exact reason for the loss of brightness or shadow in the heated steel, but he had learned that this was the point when the right hardening temperature had been reached, and by observing it he was able to harden at a temperature determined by the same principle as is employed in modern means of determining the recalescence point. It has generally been believed that the earliest observer of this phenomenon was the Russian, Chernoff, who about 1860 called attention to this characteristic of steel when heated. The practical value of these observations was finally clearly laid down by Brinell."

COMMITTEES FOR ANNUAL CONVENTION OF AMERICAN SOCIETY FOR STEEL TREATING

FOLLOWING is given both the national and local committees which have been selected for the annual Convention and Exhibition of the Society, which is to be held in Detroit, Oct. 2 to 7, 1922:

General Chairman

W. P. Woodside, 698 Webb avenue, Detroit. Phone, Hemlock 4276. Studebaker Corp., Phone, Northway 3940.

Representative of National Society

A. E. White, University of Michigan, Ann Arbor, Mich.

National Meetings and Papers Committee

Chairman—C. N. Dawe, 2426 Longfellow avenue, Phone, Hemlock 6414W. Studebaker Corp., Phone, Northway 3940.

J. M. Watson, Member W. C. Peterson, Member C. G. Heilman, Member

LOCAL COMMITTEES

Finance

Chairman—C. T. Bragg
N. G. Banks
L. A. Danse
W. A. Gowan
J. F. McCady
L. D. Sullivan
A. A. Tredway
E. P. Young
W. G. Calkins

Transportation

Chairman—W. B. Hurley
Dale Bauer
Lee Chamberlain
J. H. Gillooley
J. F. Torrence
B. W. Upham
J. H. Watson

Information

Chairman—Robt. Atkinson
J. D. Boyle
H. M. Brey
A. C. Downer
A. T. Haggerty
Homer Hood
R. E. Laner
Don Perry
Harold Peebles
L. Thomas
J. E. Voight
Garden Webb
E. L. Blake

Exhibition

Chairman—Jack Dailey
Jack Billingsley
T. P. Braunigan
L. B. Case
E. J. Hurgmoether
K. L. Herrmann
A. A. Lauppe
T. E. McCleary
J. C. McCabe
H. A. Neil
F. H. Ragan
H. L. Shippy
C. L. Stafford

Entertainment

Chairman—Frank Davis
Joe Bourg
G. W. Fellingham
Harry Askew
D. P. Harr
E. L. Hollister
Ed. Kottnauer
John Andrews
A. F. McFarland
Syd. Norwood
Carl Pfeifer
Arthur Schaffer
Ed Graham

Publicity

Chairman—E. W. Guibert
N. C. Banks
W. E. Blythe
H. G. Geissinger
A. E. Grinnell
H. M. Lane
J. C. McCabe
J. F. Newman
H. L. Shippy
F. P. Zimmerly

Hotel

Chairman—D. J. Crowley
G. P. Beck
W. J. Clark
L. C. Dunn
G. M. Hawthorne
Walter Jominy
G. W. Landrus
A. S. Lee
C. C. Rous
Arthur Schaffer
W. W. Wilson

Ladies

Chairman—W. J. Learmonth
D. D. Dodd
Harry Askew
Ed. Graham
M. L. Hollister
Syd. Norwood
Stanley Sowder
Lloyd Woodside
G. A. Willet

EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF ONE PER CENT CARBON STEEL

By H. J. French and W. George Johnson

DURING 1920 there was brought to the attention of one of the authors the lack of adequate information in the literature regarding the most suitable heat treatments for production of the best combinations of strength and ductility for one per cent carbon steel. While considerable data are available relating to tensile properties of high carbon alloys, it was not possible to make satisfactory comparisons between the results reported by various investigators as to the effectiveness of different treatments for the purpose in view, due to the differences in chemical composition, size of specimens treated and other factors.

Because of the varied applications of slightly supersaturated carbon steels, including tools, dies, bearings and springs, tests were made to correlate properties and structure and to determine the magnitude of the effects observed with varying time-temperature relations in certain heat treating operations. At the same time treatments resulting in the best tensile and impact properties were sought.

Among the tests previously reported the following are considered of more particular interest in the treatment of one per cent carbon steel or deal with variables studied by the authors.

Sargent[1] found greatly increased strength with increase in annealing temperatures above the critical range and a maximum when cooled from 1025 degrees Cent. (1877 degrees Fahr.) which was decreased about 38 per cent when the temperature was raised to 1150 degrees Cent. (2102 degrees Fahr.). Maximum ductility was obtained in slow cooling from the upper end of the critical range, while temperatures even moderately above this reduced the elongation and reduction of area to very low values. The accompanying microstructural changes were marked and it was found that after annealing at 915 degrees Cent. (1670 degrees Fahr.), the cementite surrounding grains of pearlite had all left the boundaries and "gone toward binding groups of pearlite crystals into larger compound crystals".

Campbell[2] also studied the annealing of one per cent carbon steel and found that maximum strength was produced after slow cooling from 905 degrees Cent. (1661 degrees Fahr.) while the highest ductility and lowest strength was obtained when using 760 degrees Cent. (1400 degrees Fahr.) which is slightly above or at the end of the Ac_1 transformation. In general the inflections in curves for strength and elastic limit were accompanied by the reverse inflections in curves for elongation and reduction of area increases in one set being obtained at loss of the other.

Both Sargent's and Campbell's results are shown graphically in Fig. 1 while in Table I are given results of tests included in the Sixth Report to the Alloys Research committee[3] for steel containing 0.95 per cent car-

[1] George W. Sargent, "A Study of the Effect of Heat Treatment on Crucible Steel Containing One Per Cent Carbon." Trans. A. I. M. E., 1901, p. 303.

[2] William Campbell, "On the Heat Treatment of Some High Carbon Steels." Proc. Amer. Soc. Test. Mats., 1906, p. 211.

[3] Sir W. Roberts—Austen and W. Gowland, Sixth Report to the Alloys Research Committee, "On the Heat Treatment of Steel." Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7.

A paper presented by title at the Indianapolis Convention. The authors, H. J. French and W. George Johnson are physicist and assistant physicist respectively, Bureau of Standards, Washington, D. C. Published by permission of the director, Bureau of Standards.

bon. Maximum strength was obtained in slow cooling from 900 degrees Cent. (1652 degrees Fahr.) and the ductility gradually decreased with rise in temperature from 720 to 1100 degrees Cent. (1328 to 2012 degrees Fahr.). Soaking decreased the strength and in general resulted in an increase in elongation but at the same time produced a decrease in reduction of area.

From the preceding results it appears that slow cooling from temperatures just above Ac_1 gives maximum ductility and low strength. With rise in annealing temperature the ductility decreases rapidly and elongation and reduction of area in general remain at low values while the strength reaches a maximum in the range about 900 degrees Cent. (1652 degrees Fahr.).

Brinell[4] showed that the hardening capacity of carbon steels increased up to 0.45 per cent carbon when it became nearly constant with further increase to 0.90 per cent and thereafter decreased. The steel under consideration is, therefore, just above the range of maximum hardening capacity and, as is well known, is sensitive to thermal treatment, having slightly more carbon than required for saturation. After quenching in cold water from temperatures above the thermal transformation, it is hard and brittle while when more slowly cooled as in oil, high strength and somewhat greater ductility results. In either case the properties are changed to a marked degree by the quenching temperature whether

[4] Axel Wahlberg, "Brinell's Method of Determining Hardness and Other Properties of Iron and Steel." Jour. I. & S. Inst., 1901, Vol. 1, p. 243.

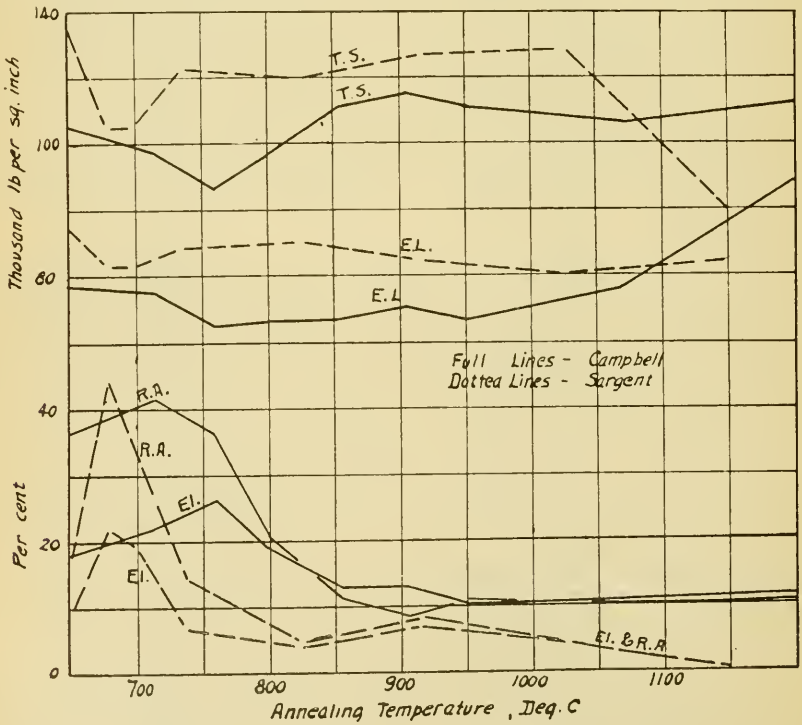

Fig. 1—Effect of different annealing temperatures on the tensile properties of 1 per cent carbon steel. Curves taken from William Campbell and G. W. Sargent

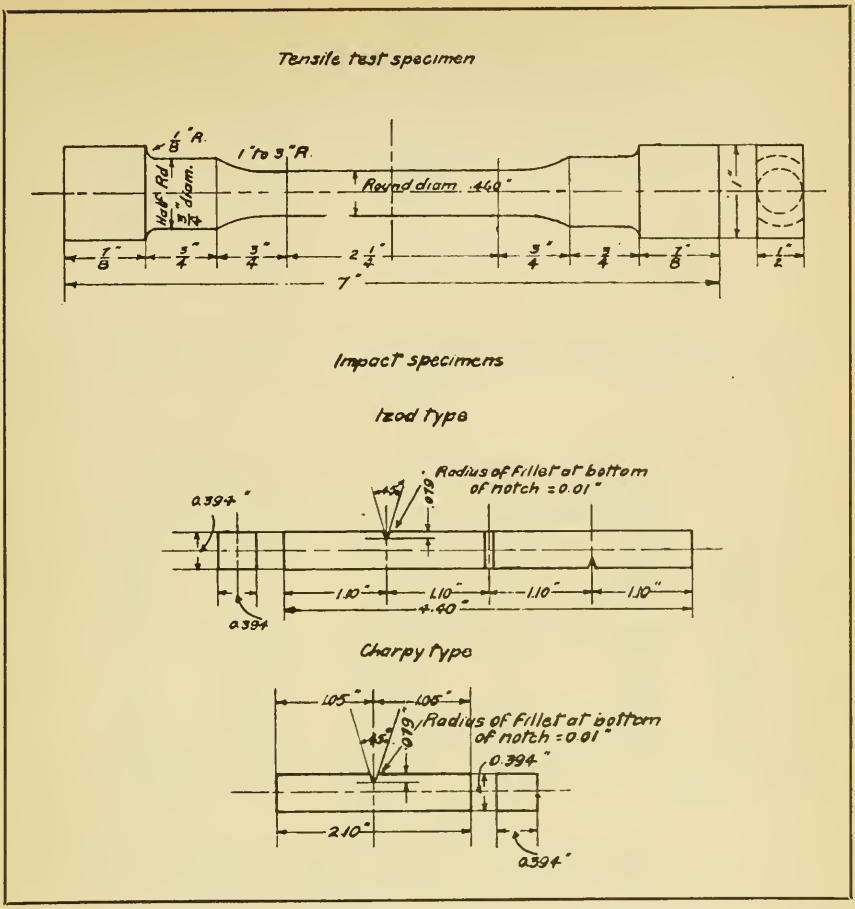

Fig. 2—Form and dimensions of test specimens used

subsequent tempering is at low or high temperatures or entirely omitted, as indicated by results reported by Roberts-Austen and Gowland[5] for an alloy containing 0.95 per cent carbon, which are reproduced in Table II. Based on their tests the authors conclude that the oil quenching temperature producing the best combination of strength, elastic limit and elongation is in the neighborhood of 900 degrees Cent. (1652 degrees Fahr.).

Hanemann[6] reported direct decrease in strength as the water hardening temperature increased from 750 to 1000 degrees Cent. (1382 to 1832 degrees Fahr.) for 1 per cent carbon steel not subsequently tempered whereas for an alloy containing 1.33 per cent carbon, the strength increased until the quenching temperature exceeded 900 degrees Cent. (1652 degrees Fahr.).

All that is considered necessary in the treatment of steel, as regards time at hardening temperature, is to maintain for the minimum period required for uniform heating throughout. The time actually required to

[5] See note 3.
[6] H. Hanemann, "Uber die Warmebehandlung der Stahle." Stahl and Eisen, 1911, 31, p. 1365.

Table I

Effect of Time and Temperature in Annealing on the Mechanical Properties of 0.95 Per Cent Carbon Steel*

Annealing temperature degrees Cent.	Annealing temperature degrees Fahr.	Time at temperature hours	Breaking strength, pounds per square inch	Elastic limit, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent
620	1148	½	118,400	76,600	15.0	27.0
		12	101,800	51,800	18.5	27.1
720	1328	½	88,000	.....	22.0	45.0
		12	75,500	31,600	23.5	35.4
800	1472	½	89,500	50,400	18.0	28.4
		12	.....	.....	....	....
900	1652	½	114,500	.....	10.0	15.4
		12	107,000	80,800	11.9	11.0
1100	2012	½	111,300	.....	7.5	9.1
		12	.....	.....	....	....
1200	2192	½	.....	.....	....	....
		12	53,900	45,000	20.0	37.5

*From Sixth Report to the Alloys Research Committee. Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7. Pounds per square inch = tons per square inch given in original table x2240.

Table II

Effect of Various Methods of Quenching and Tempering on the Tensile Properties of 0.95 Per Cent Carbon Steel*

Quenched from degrees Cent.	Quenched from degrees Fahr.	Tempered at degrees Cent.	Tempered at degrees Fahr.	Breaking strength, pounds per square inch	Yield point, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent
Quenched in Water at 20 Degrees Cent. (68 Degrees Fahr.)							
720	1328	...	...	125,500	.....	12.0	24.8
900	1652	...	...	48,400	.....	Nil	Nil
1200	2192	...	...	9,400	.....	Nil	Nil
Quenched in Oil at 80 Degrees Cent. (176 Degrees Fahr.)							
720	1328	...	...	117,100	89,500	13.0	19.8
720	1328	350	662	122,500	81,700	12.0	18.6
870	1598	350	...	229,500	149,400	7.0	17.0
1000	1832	350	...	211,000	152,700	5.5	14.8
800	1472	600	1112	103,000	80,000	12.0	12.9
900	1652	600	...	110,000	90,000	17.0	28.0

*From Sixth Report to the Alloys Research Committee. Proc. Inst. Mech. Eng., 1904, Vol. 1, p. 7. Pounds per square inch = tons per square inch given in original table x2240.

Table III

Effect of Time of Heating Prior to Hardening on the Mechanical Properties of 1.08 Per Cent Carbon Steel*

Time of heating at 800 degrees Cent. minutes	Maximum strength, pounds per square inch	Elastic limit, pounds per square inch	Elongation in 100 millimeters (3.94 inches) per cent	Reduction of area, per cent	Brinell hardness
2	91,500	78,300	10.5	17.2	600
20	121,000	121,000	10.5	17.2	571–652
60	125,000	122,000	10.5	17.2	875

*A. Portevin: "Influence du Temps de Chauffage avant la Trempe sur les Resultats de cette Operation." Rev. Met. (1916), 13, p. 9. Pounds per square inch = kilograms per square millimeter given in original tables x 1.422 x 103.

Table IV

Effect of Tempering on the Mechanical Properties of Hardened 1 Per Cent Carbon Steel*

Samples Quenched In Oil from 790 Degrees Cent. (1454 Degrees Fahr.)

Tempered at degrees Cent.	Tempered at degrees Fahr.	Tensile strength, pounds per square inch	Yield point, pounds per square inch	Elongation in 2 inches, per cent	Reduction of area, per cent	Brinell hardness	Impact energy absorbed (Charpy foot-pounds per square inch
...	...	192,500	127,000	10.5	34.0	387	..
375	707	195,000	127,500	12.5	34.0	375	42
460	860	201,500	111,000	12.5	40.3	402	41
560	1040	168,500	104,500	14.5	30.7	321	54
650	1202	134,000	86,000	20.0	40.3	277	57
As rolled		152,000	86,000	9.5	13.3	302	27

*J. H. Nead: "The Effect of Carbon on the Physical Properties of Heat Treated Carbon Steel." Trans. A. I. M. E., 53 (1915), p. 218. "Charpy Results as Related to Carbon Content of Steel, Tests of Metals," etc., 1916, p. 109.

meet this condition is known to increase markedly with size and it is also known that with increased mass the temperature at which the steel will first harden, rises. Portevin[7] has shown that the effect of time of heating prior to quenching is marked and that a change from 2 to 60

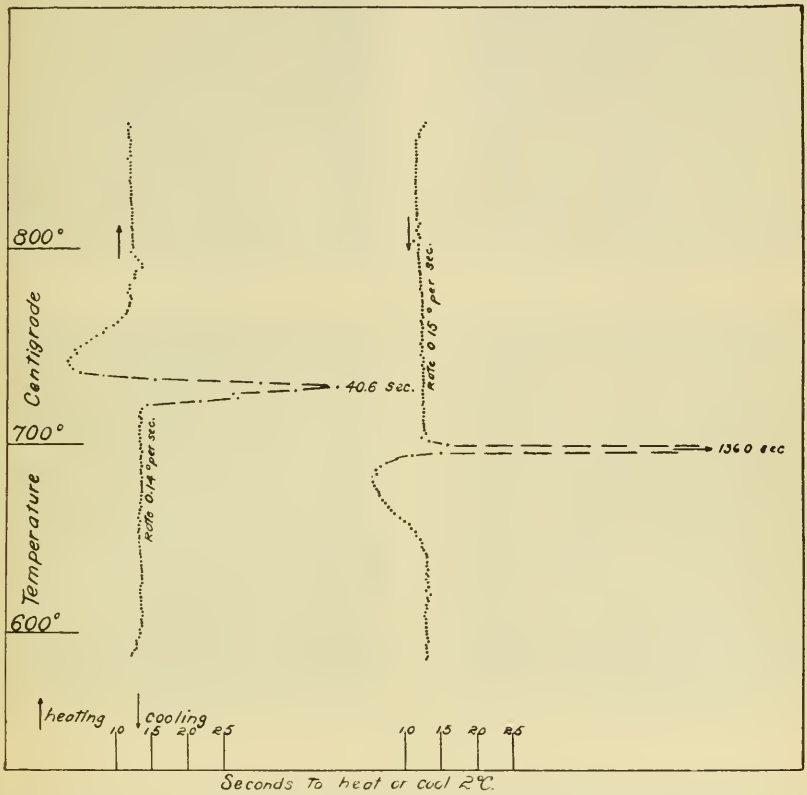

Fig. 3—Inverse rate heating and cooling curves of 1 per cent carbon steel. Data for Ac_1: Begins 716 degrees Cent.; maximum 727 degrees Cent.; ends 740 degrees Cent. Data for Ar_1: Begins 703 degrees Cent.; maximum 698 degrees Cent.; ends 680 degrees Cent.

minutes resulted in increased strength and hardness as shown in Table III.

The effects of tempering on the tensile and impact properties of hardened 1 per cent carbon steel have been studied by a number of investigators, including Rudeloff[8], Hanemann[9] and Roberts Austen and Gowland[10]. More recently J. H. Nead[11] determined the tensile and impact properties of such steel quenched in oil from the recommended annealing temperature range of the American Society for Testing Mate-

[7] A. Portevin, "Influence due temps de chauffage avant la trempe sur les resultats de cette operation." Rev. Met., 1916, 13, p. 9.

[8] M. Rudeloff, "Untersuchungen uber den Einfluss des Ausgluhens auf die physikalischen Eigenschaften von Eisen-und Stahdrahten." Stahl und Eisen, 1892, 12, p. 63.

[9] See note 6.

[10] See note 3.

[11] J. H. Nead, "The Effect of Carbon on the Physical Properties of Heat-Treated Carbon Steel." Trans. Amer. Inst. Min. Eng. 53, 1915, p. 218. "Charpy Results as Related to Carbon Content of Steel." Tests of Metals, etc., 1916, p. 109.

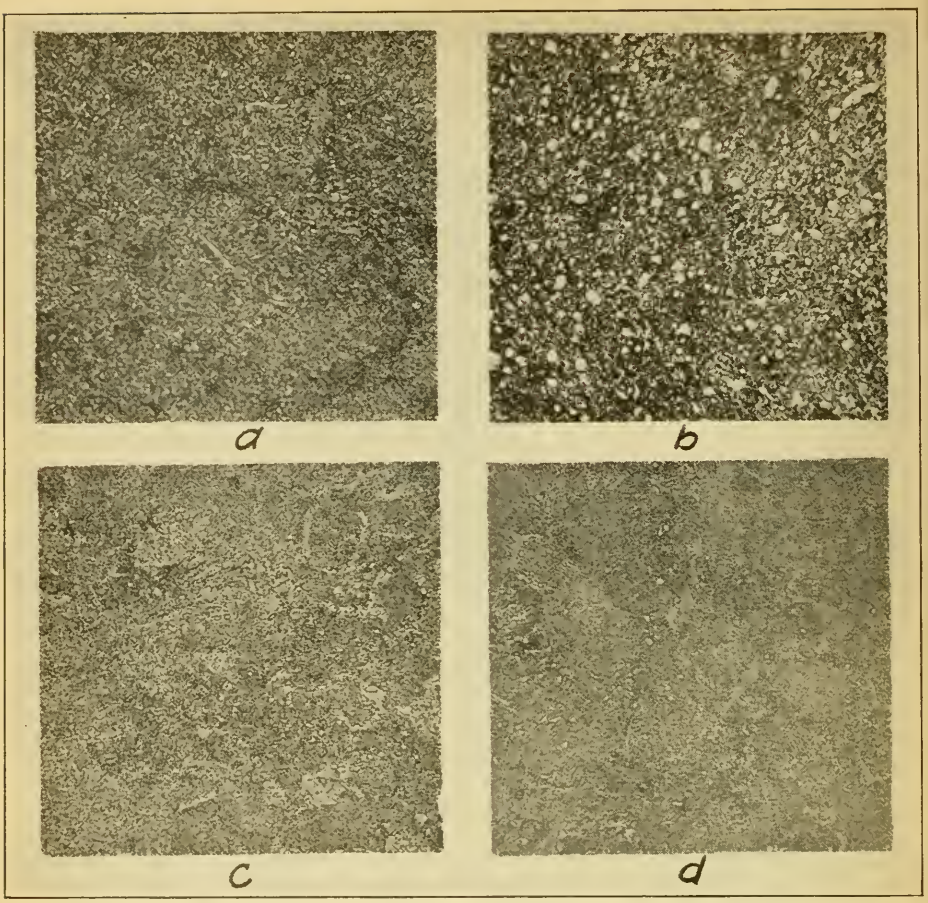

Fig. 4—Microstructure of 1 per cent carbon steel quenched from 788 degrees Cent. in different media and tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched in water. *b* quenched in oil. *c* quenched in molten lead at 538 degrees Cent. *d* quenched in molten sodium and potassium nitrates at 538 degrees Cent.

rials[12] when followed by tempering at various temperatures but the possibilities for production of high combinations of strength and ductility by varying hardening and tempering treatments have not been fully covered. It appears from Nead's results reproduced in Table IV that tempering has a relatively small effect in reducing the brittleness of the oil quenched steel and that tempering temperatures in the neighborhood of 500 degrees Cent. (932 degrees Fahr.) are required for a material increase in ductility or decrease in tensile strength. The cause of this is undoubtedly in incomplete hardening as specimens ½-inch or more in diameter will not be martensitic throughout after quenching in oil.

It is well recognized that a long time in tempering hardened steel at a given temperature is, within limits, equivalent to tempering for a short time at a higher temperature. Long time tempering at a given temperature increases the ductility and lowers the strength and hardness, but

[12] Year Book of the Amer. Soc. for Test. Materials, 1914, p. 201.

the magnitude of these effects, especially at the lower tempering temperatures, depends upon the thoroughness of the hardening. The fact that Hayward and Raymond[13] found relatively small effects on the tensile properties of 0.45 per cent carbon steel with increased time of tempering was probably due in part to incomplete hardening as pointed out in discussion of their results.

Mathews and Stagg[14] give detailed data relating to this subject and

[13] C. R. Hayward and S. S. Raymond, "Effect of Time on Reheating Hardened Carbon Steel Below the Critical Range." Trans. A. I. M. E., 1916, p. 517.
[14] J. A. Matthews and H. J. Stagg, "Factors in Hardening Tool Steel." Trans. Amer. Soc. Mech. Eng., 1914, p. 845.

Table V

Effect of Time in Tempering Hardened Steel*

Elastic limit, pounds per square inch	Maximum strength, pounds per square inch	Elongation, per cent	Reduction of area, per cent	Brinell hardness	Treatment
228,750	260,137	2.5	....	425	1550° F. oil, 800° F. 8 minutes
201,125	214,562	11.6	45.4	390	1550° F. oil, 800° F. 20 minutes
175,000	183,187	12.0	49.35	340	1550° F. oil, 800° F. 40 minutes

Results are average of four check tests after each treatment, carried out on ½-inch round tensile test bars.

*J. A. Matthews and H. J. Stagg: "Factors in Hardening Tool Steel," Trans. A. S. M. E., 1914, p. 845.

Table VI

Influence of Temperature on Time of Cooling in Quenching 1 Per Cent Carbon Steel*

Weight of specimen grams	Quenching temperature, degrees Cent.	Cooling time to 100 degrees Cent. in seconds
12.5	950	3.07
12.3	845	4.43
12.4	750	4.11
12.3	703	5.73
12.2	695	6.2

*C. Benedicks: "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Journ. I. & S. Inst., 1908, Vol. 2, p. 153.

Table VII

Effect of Time at 760 Degrees Cent. Prior to Oil Quenching on the Hardness of 1 Per Cent Carbon Steel

Heated at 760 degrees Cent. (1400 degrees Fahr..) for time specified and oil quenched	Brinell hardness
30 minutes	340
1 hour	351
5 hours	364

Table VIII

Comparison of Oil and Water Hardening of 1 Per Cent Carbon Steel for Production of Definite Strengths

Strength chosen, pounds per square inch	Method of hardening, degrees Cent.	Tempering required, degrees Cent.	Tempering required, degrees Fahr.	Proportional limit, pounds per square inch	Elastic ratio per cent	Elongation in 2 inches, per cent	Reduction of area, per cent	Hardness Brinell	Hardness Shore
200,000	843—oil	489	912	125,000	62.5	10.5	27.5	400	56
	788—oil	331	628	125,000	62.5	10.0	29.0	370	53
160,000	843—oil	611	1132	102,500	64.0	14.0	38.5	312	46
	788—oil	591	1096	101,500	63.5	15.5	42.2	302	44
	788—water	540	1004	136,500	85.3	12.0	32.0	342	54
135,000	843—oil	690	1274	88,000	65.1	19.5	48.0	260	41
	788—oil	661	1222	87,500	64.8	18.5	45.5	265	39
	788—water	608	1126	118,000	87.3	17.0	42.0	290	47
120,000	788—oil	696	1284	78,000	65.0	20.0	48.0	240	37
	788—water	648	1198	107,000	89.0	19.0	48.0	260	43

their values are reproduced in Table V. In part they state "..... time at the drawing temperature has a marked effect. The act of breaking down the martensite is progressive and not sharply defined. Both time and temperature have their effects."

Similarly other investigators have shown the importance of the time

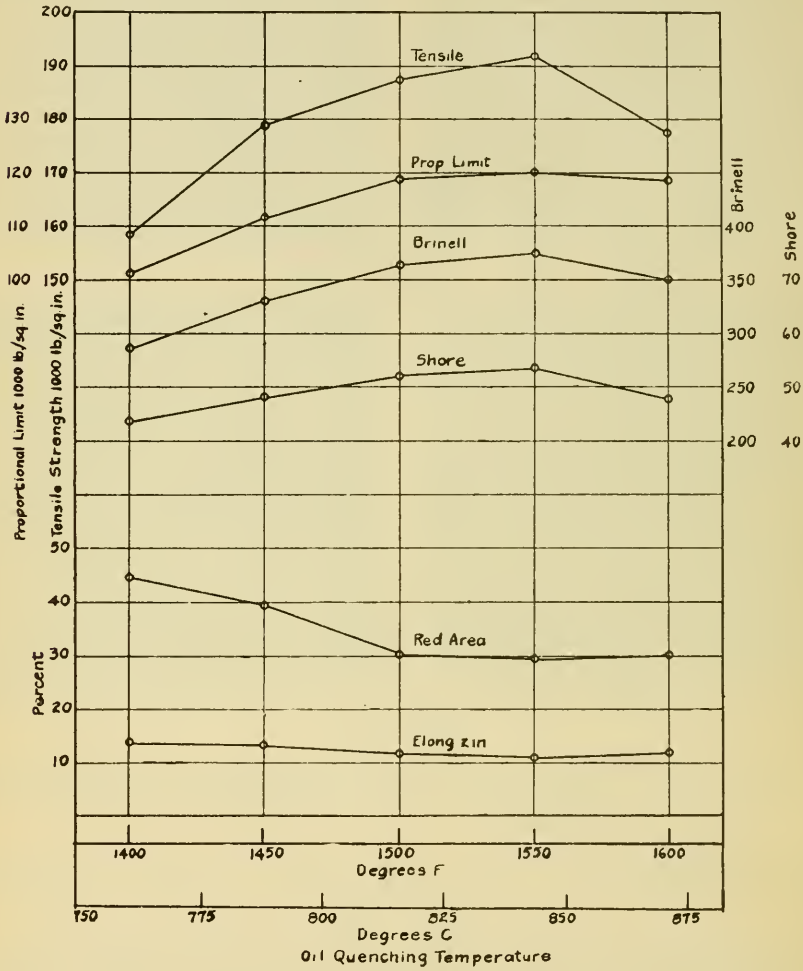

Fig. 5—Effect of varying oil quenching temperatures on mechanical properties of 1 per cent carbon steel subsequently tempered at 538 degrees Cent.

effect in tempering notably Barus and Stroubal[15] who used thermoelectric methods; Goerens[16] who studied variations in tensile, magnetic and other properties of low carbon steel; Portevin[17] who carried out hardness

[15] Barus and Stroubal, "On the Physical Characteristics of Iron Carburets." Bull. 14, U. S. Geol. Survey, 1885.

[16] P. Goerens, "Influence du Traitment thermique sur les proprietes de l'acier ecruit." Rev. Met. Memoires, 1913, 10, p. 1337.

[17] A. Portevin, "Influence du temps de chauffage avant le trempe sur les resultats de cette operation." Rev. Met., 1916, 13, p. 9.

tests; and microscopic examination, conducted by Rudeloff[18] and Hanemann[19]

The steel tested was part of a lot of 1-inch hot rolled bars of varying carbon contents supplied by the Carnegie Steel Co., Pittsburgh, and of the following chemical composition:

	Per Cent
Carbon	1.04
Manganese	0.17
Phosphorus	0.017
Sulphur	0.019
Silicon	0.14

After cutting to the desired lengths for tensile and impact specimens, the steel was normalized by heating to 815 degrees Cent. (1500 degrees Fahr.) for 30 minutes and cooling in still air, thereafter showing the following tensile properties and hardness:

Tensile strength, pounds per square inch	129,900
Proportional limit, pounds per square in	55,000
Elongation in 2 inches, per cent	14.0
Reduction of area, per cent	22.3
Brinell hardness	217
Shore hardness	32

Test samples were machined to slightly larger than the required size, approximately one-half round in reduced section, subjected to various heat treatments and finally ground wet to the form and dimensions shown in Fig. 2. Tensile tests were made with a 50,000-pound testing machine and a strain gage was used in determination of the limit of proportionality, while hardness was obtained by both the Shore and Brinell methods, by means of a recording scleroscope and an American Brinell hardness testing machine, the latter under standard conditions of 3000 kilogram load and 10 millimeter ball. Impact specimens of both Izod and Charpy types were tested in American made Izod and Charpy machines. Prior to subjecting the steel to heat treatment the thermal transformations were determined in a manner already described by Scott and Freeman[20]. The heating and cooling curves so obtained are shown in Fig. 3.

In order to throw further light on the effect of several methods of hardening 1 per cent carbon steel when followed by high tempering such as would possibly bring it into suitable condition for structural purposes, samples were quenched in water, oil, molten lead and a hot salt mixture consisting of 2 parts by weight of potassium nitrate and 3 parts sodium nitrate. The details of these treatments and test results are given in Table IX and it is evident that the surface of the treated metal is an important and determining factor in the tensile properties obtained. Removal of surface irregularities resulting from scaling in treatment including a large part or all of the decarburized surface results in better combinations of strength and ductility but the steel is brittle, as shown by the low impact values, regardless of the quenching method employed. In general, the most marked effect of grinding after treatment is found in values of reduction of area, which greatly increase.

It appears that the highest strength and ductility are obtained by cooling in oil but a much higher elastic ratio results from water quenching. It does not necessarily follow, however, that the results reported

[18] See note 8.

[19] See Note 6.

[20] H. Scott and J. R. Freeman Jr., "Use of a Modified Rosenhain Furnace for Thermal Analysis.' Bureau of Standards Scientific Paper 348, Oct. 24, 1919.

for any quenching method are the best which may be produced, for it is possible that better combinations of strength and ductility may be obtained when using higher quenching temperatures than 788 degrees Cent. (1450 degrees Fahr.) as is true when cooling in molten lead as shown in Table IX.

The structures of this steel after application of these different treatments are shown in Fig. 4 and after quenching in water or oil followed by tempering at 538 degrees Cent. (1000 degrees Fahr.) the steel is sorbitic. When quenched in molten lead or salt the steel consists of sorbitic pearlite but the transformation appears to have progressed somewhat further to pearlite in the case of the lead quenching.

The effect of different oil quenching temperatures on the properties and structure of steel subsequently tempered at 532 degrees Cent. (1000 degrees Fahr.) is marked as shown in Table XI and Figs. 5 and 6. With a rise in temperature to 843 degrees Cent. (1550 degrees Fahr.) strength and limit of proportionality increase and elongation and reduction of area decrease. With further rise in quenching temperature, the strength factors decrease with practically no change in ductility but in all cases the resistance to impact is low.

Benedicks[21] has shown that an increase in temperature results in more rapid cooling, for steel of constant mass and that the metal passes more rapidly through the transformations. His results for an alloy containing one per cent carbon are reproduced in part in Table VI.

It is quite evident, therefore, that a hardening of the matrix of the steel under investigation should result with rise in quenching temperatures and more carbide should be held in solution. In this case, however, there is an added factor contributing to the increased hardness and strength shown in Fig. 5 in the retention of the excess cementite when quenching from above its solution temperature range. The rate of cooling in oil when the steel is heated to 843 degrees Cent. (1550 degrees Fahr.) is not sufficiently rapid to retain all this carbide in solution but an increase to 871 degrees Cent. (1600 degrees Fahr.) increases the cooling rate through the transformations enough to cause retention of the few remaining globules found after the first mentioned treatment. These structures as well as those obtained on using lower quenching temperatures are shown in Fig. 6 and because of the tempering at 538 degrees Cent. (1000 degrees Fahr.), the ground mass is sorbitic. There is free cementite present in good proportion until quenching temperatures above 816 degrees Cent. (1500 degrees Fahr.) are used, while the condition of maximum strength obtained in the sample quenched from slightly above the Acm transformation, is coincident with the minimum proportion of free carbide. Undoubtedly the cementite is first wholly retained in quenching from a temperature somewhat below 871 degrees Cent. (1600 degrees Fahr.) where the first disappearance has been noted and possibly this condition would be coincident with higher strength than shown in Fig. 5. However, it is acknowledged that each increase in temperature is accompanied by increased grain size. This effect opposes whatever beneficial results might be obtained by total retention of the cementite and will finally induce greater brittleness and lowered tensile strength and that this has happened in the range under consideration is shown by

[21] C. Benedicks, "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Jour. I. & S. Inst., 1908, Vol. 2, p. 153.

Fig. 6—Microstructure of 1 per cent carbon steel, oil quenched from various temperatures and subsequently tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched from 760 degrees Cent. (1400 degrees Fahr.). *b* quenched from 788 degrees Cent. (1450 degrees Fahr.). *c* quenchd from 816 degrees Cent. (1500 degrees Fahr.). *d* quenched from 843 degrees Cent. (1550 degrees Fahr.). *e* quenched from 871 degrees Cent. (1600 degrees Fahr.)

Table IX

Mechanical Properties of 1 Per Cent Carbon Steel Quenched from 788 or 843 Degrees Cent. in Different Media and Subsequently Tempered at 538 Degrees Cent.

Treatment	Sample No. *	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pounds Charpy Values	Charpy Average	Izod Values	Izod Average
788 degrees Cent. (1450 degrees Fahr) 30 minute water quench. Tempered 15 to 20 minutes, 538 degrees Cent. (1000 degrees Fahr.)	51 B	165,500	143,000	11.0	27.7	340	56				
	52 B	156,200	132,000	12.5	34.6	340	53	2.5–3.1–3.2	2.9	2.2–2.2–2.0	2.2
	49 A	114,400	98,900	14.0	23.1	262	42				
	50 A	116,200	101,400	15.0	26.1	255	43				
843 degrees Cent. (1550 degrees Fahr.) 30 minutes water quench. Tempered 15 to 20 minutes 538 degrees Cent. (1000 degrees Fahr.)	49 B	171,650	130,000	9.5	31.4	340	51				
	50 B	160,800	125,000	10.5	31.0	340	45				
	51 A	143,200	82,000	6.5	11.5	294	46				
	52 A	138,500	92,000	7.5	8.2	286	46				
788 degrees Cent. (1450 degrees Fahr.) 30 minute oil quench. Tempered 15 to 20 minutes 538 degrees Cent. (1000 degrees Fahr.)	3 B	188,250	110,500	....	....	340	48				
	4 B	169,000	113,000	13.0	39.3	318	48				
	13 A	157,500	92,500	11.0	16.5	321	48	3.0–3.5–2.3	2.9	2.0–2.0–3.0	2.3
	14 A	156,100	90,000	10.5	16.1	321	48				
788 degrees Cent. (1450 degrees Fahr.) 30 minute salt quench at 538 degrees Cent. (1000 degrees Fahr.) holding 15 minutes before cooling in oil.	43 B	133,700	90,500	14.5	35.0	294	42				
	44 B	147,000	80,500	14.5	36.0	289	40	3.9–3.6–3.4	3.8	4.2–3.4–3.8	3.8
	7 A	143,000	81,500	8.5	22.5	278	39				
	8 A	142,900	77,500	8.5	17.0	294	42				
788 degrees Cent. (1450 degrees Fahr.) 30 minute lead quench at 538 degrees Cent. (1000 degrees Fahr.), holding 15 minutes before cooling in oil. 843 degrees Cent. (1550 degrees Fahr.) 1 hour lead quench at 538 degrees Cent. (1000 degrees Fahr.), holding 30 minutes before cooling in oil.	47 B	151,800	84,000	15.0	37.4	255	37				
	48 B	148,200	81,000	14.5	36.3	278	37	3.2–3.5–3.0	3.2	3.1–3.0–3.3	3.1
	9 A	130,800	71,000	10.0	12.6	238	38				
	10 A	131,200	68,500	9.5	12.4	228	31				
	25 A	136,700	70,000	12.0	23.2	248	33				
	26 A	139,200	72,500	10.0	15.2	278	36				

*Samples marked B were ground wet after treatment and before testing; those marked A were tested without grinding after heat treatment.

Table X

Effect of Time Slightly Below Ac_1 on the Mechanical Properties of 1 Per Cent Carbon Steel Previously Oil Quenched from 843 Degrees Cent.

Specimen No.	Heated at 704 degrees Cent. (1300 degrees Fahr.) for time specified and then oil quenched. Hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Izod
23 B	½	126,200	86,000	18.8	46.7	260	40	3.3–3.0	3.0–2.8–3.0
24 B		140,200	.....	17.0	40.2	248	40		4.5–5.5–6.0
Average		133,200	86,000	17.9	43.4	254	40	3.2	4.1
34 B	1	121,500	79,000	....	....	241	39		
64 B		113,200	81,500	19.0	48.4	235	39		
Average		117,350	80,250	...	....	238	39		
35 B	5	86,100	54,500	33.0	61.3	156	32	2.8–8.4–2.5	2.6–2.3–3.9
36 B		93,900	72,000	....	....	207	34		
Average		90,000	63,250	....	....	182	33	4.6	2.9

the sharp decrease in strength between samples quenched from 843 and 871 degrees Cent. (1550 and 1600 degrees Fahr.).

In order to further investigate the magnitude of the effects of "soaking" at various hardening temperatures, samples were held for different intervals at 760 degrees Cent. (1400 degrees Fahr.) and 843 degrees Cent.

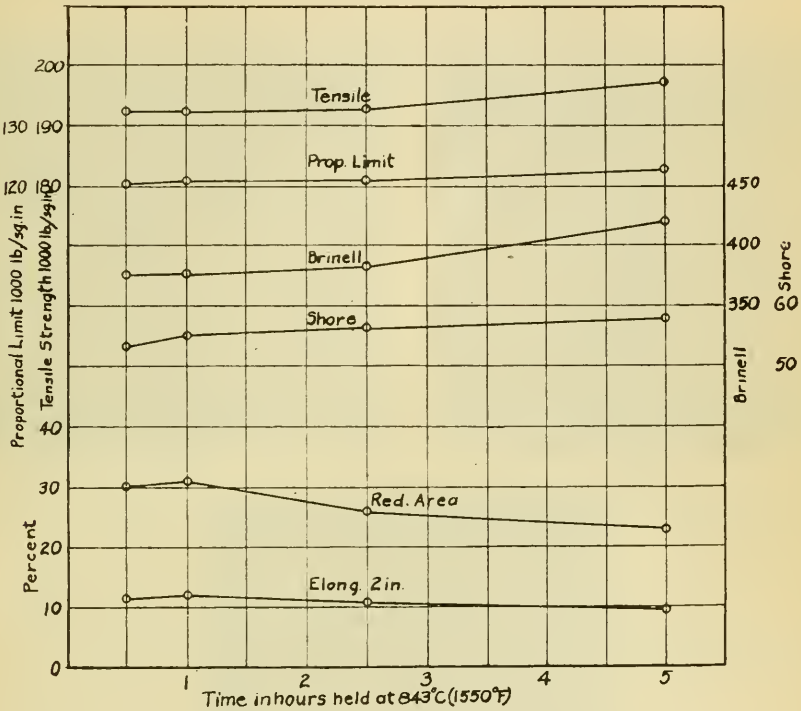

Fig. 7—Effect of time at 843 degrees Cent. on the mechanical properties of 1 per cent carbon steel subsequently oil quenched and tempered at 538 degrees Cent.

(1550 degrees Fahr.) prior to quenching in oil and tempering. The first temperature is just above or at the end of Ac_1 while the latter is slightly above the temperature range at which the excess carbide goes into solution.

The time over 30 minutes for which the steel is held at 843 degrees Cent. (1550 degrees Fahr.) when subsequently oil quenched and tempered at 538 degrees Cent. (1000 degrees Fahr.) has a relatively small effect on the tensile and impact properties, as shown in Fig. 7 and Table XII. A change from 30 minutes heating to 1 hour does not alter the strength appreciably but results in slightly increased ductility whereas with increase in time of soaking from 1 to 5 hours the hardness, tensile strength and proportional limit gradually increase with accompanying decrease in elongation and reduction of area. The steel is very brittle after all treatments and the variations in impact resistance are not such as to allow conclusions to be drawn.

The hardening temperature chosen is only slightly above the solution temperature of the excess carbide which, according to recent determina-

tion of Ishiwara[22] takes place at about 835 degrees Cent. (1535 degrees Fahr.) and that this reaction proceeds slowly is at once evident from examination of the structures shown in Fig. 8. Solution is incomplete at 30 to 45 minutes whereas in 2½ hours this change has progressed nearly to completion, coincident with a marked decrease in reduction of area in tensile test. In the sample heated for 5 hours that excess carbide is

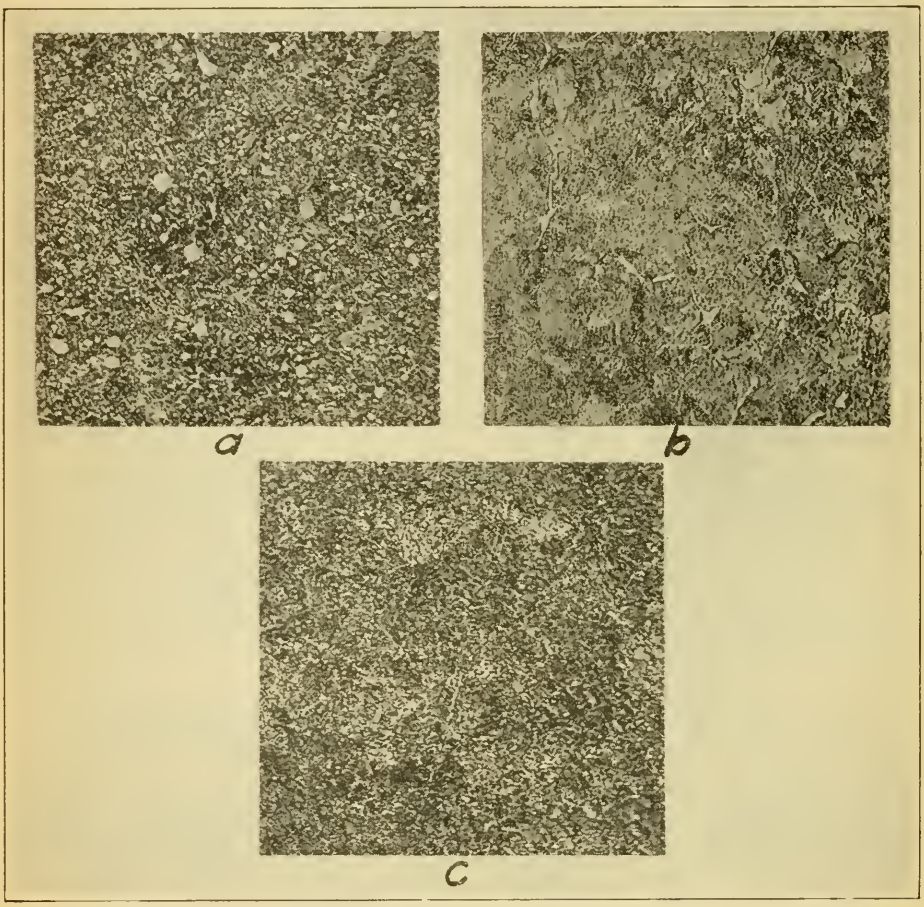

Fig. 8—Microstructure of 1 per cent carbon steel held at 843 degrees Cent. for various times and subsequently oil quenched and tempered at 538 degrees Cent. Etched with 2 per cent nitric acid in alcohol and X 500. *a* held 45 minutes. *b* held 2½ hours. *c* held 5 hours

wholly in solution which partly accounts for the increased hardness obtained.

When this steel is soaked at 760 degrees Cent. (1400 degrees Fahr.) which is slightly above the end of the Ac_1 transformation, oil quenched and subsequently tempered as in the preceding samples marked changes in properties result as illustrated in Fig. 9 and Table XIII. An increase in time at hardening temperature from 30 minutes to 2 hours results in in-

[22] Torajuro Ishiwara, "On the Magnetic Determinations of A_0, A_1, A_2, and A_3 Points in Steels Containing Up to 4.8 Per Cent Carbon." Science Reports of the Tohoku Imperial Univ., Vol. 9, No. 5, p. 401.

Table XI

Effect of Varying Oil Quenching Temperatures on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Tempered at 538 Degrees Cent.

Specimen No.	Heated to temperatures noted, held 30 minutes and quenched in oil.* Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per Cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pound Charpy	Impact Energy Absorbed, Foot Pound Izod
1 B	760	1400	158,000	101,000	13.5	44.3	288	43	2.2–2.5–3.0	2.3–2.2–2.5
60 B			.....	.....	....	....	...	..		
Average			.....	.....	....	....	...	..	2.6	2.3
3 B	788	1450	188,250	110,500	....	....	340	48	3.0–3.5–2.3	2.0–2.0–3.0
4 B			169,000	113,000	13.0	39.3	318	48	3.0–3.5–2.3	2.0–2.0–3.0
Average			178,600	111,750	13.0	39.3	329	48	2.9	2.3
5 B	816	1500	193,600	122,000	10.0	29.2	364	54	3.1–3.3–3.6	
6 B			181,600	116,000	12.5	31.0	364	50		
Average			187,600	119,000	11.2	30.1	364	52	3.3	
7 B	843	1550	199,000	121,000	10.5	29.5	364	53	3.1–3.3–3.1	3.1–3.2–3.1
8 B			185,000	119,000	11.5	29.5	387	54		
Average			192,000	120,000	11.0	29.5	376	54	3.2	3.1
9 B	871	1600	177,900	118,000	11.5	30.3	345	46	3.2–3.9–3.9	3.1–2.8–3.1
10 B			177,100	119,000	12.5	29.8	356	50		
Average			177,500	118,500	12.0	30.0	350	48	3.7	3.0

*All samples subsequently tempered at 538 Degrees Cent. (1000 degrees Fahr.) for 20 minutes and cooled in oil.

Table XII

Effect of Time at 843 Degrees Cent. on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Tempered at 538 degrees Cent.

Specimen No.	Heated to 843 degrees Cent. (1550 degrees Fahr.) for time noted and oil quenched. Tempered 20 minutes at 538 degrees Cent. (1000 degrees Fahr.) hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Impact Energy Absorbed Foot Pound Izod
7 B	½	199,000	121,000	10.5	29.5	364	53	3.1–3.3–3.1	3.1–3.2–3.1
8 B		185,000	119,000	11.5	29.5	387	53		
Average		192,000	120,000	11.0	29.5	376	53	3.2	3.1
27 B	1	202,100	128,000	10.5	27.7	387	56		
28 B		181,800	113,000	12.5	34.4	364	54		
Average		191,950	120,500	11.5	31.0	376	55		
65 B	2½	192,350	121,000	11.0	26.3	376	55		
29 B		193,400	120,500	9.5	26.6	387	57		
Average		192,875	120,750	10.2	26.4	382	56		
31 B	5	207,900	129,500	8.5	19.5	477	56	3.2–3.2–4.0	3.1–3.1–3.0
32 B		187,000	116,000	10.5	27.0	364	59		
Average		197,450	122,750	9.5	23.2	421	58	3.5	3.1

Table XIII

Effect of Time at 760 Degrees Cent. on the Mechanical Properties of 1 Per Cent Carbon Steel Subsequently Oil Quenched and Tempered at 538 Degrees Cent.

Specimen No.	Time at Oil Quenching Temperature of 760 Degrees Cent. (1400 degrees Fahr.) Hours	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Impact Energy Absorbed Foot Pound Izod
25 B	½	186,800	117,500	11.0	38.1	321	45	3.1–2.9–3.0	2.8–2.7–3.0
26 B		170,000	108,000	11.5	41.6	304	40		
Average		175,400	112,750	11.2	39.8	313	43	3.0	2.8
37 B	1								
38 B		183,250	117,000	10.5	36.8	358	53		
Average									
39 B	2	192,800	119,000	9.5	25.2	382	56		
40 B		198,700	120,000	10.5	29.3	387	60		
Average		195,750	119,500	10.0	27.2	385	58		
41 B	5	192,500	118,500	8.0	20.9	376	58		
42 B		192,000	120,000	8.5	24.0	398	58		
Average		192,250	119,250	8.2	22.4	387	58		

Table XIV

Effect of Tempering on the Mechanical Properties of 1 Per Cent Carbon Steel First Quenched in Water from 788 Degrees Cent.

Specimen No.	Held 20 minutes at tempering temperature indicated and air cooled. Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed, Foot Pound Charpy	Impact Energy Absorbed, Foot Pound Izod
51 B	538	1000	165,500	143,000	11.0	27.7	340	56	2.5–3.1–3.2	2.2–2.2–2.0
52 B			156,200	132,000	12.5	34.6	340	53		
Average			160,850	137,500	11.8	31.2	340	54	2.9	2.1
53 B	649	1200	.....	106,500	17.0	47.4	255	43		
54 B			118,800	106,000	22.0	48.6	255	43	3.2–2.6	2.3–2.0–2.1
Average			.....	106,250	19.5	48.0	255	43	2.9	2.1
55 B	704	1300	108,400	91,000	....	....	223	34	5.7–10.7–8.5	11.0–5.5–7.7
56 B			108,700	95,000	25.0	52.9	220	34	3.0–2.9–2.8	2.0–2.4–2.3
Average			108,650	93,000	....	....	222	34	5.6	5.2
67 B	760	1400	124,400	68,000	16.5	37.0	255	34	3.2–2.3–2.7	2.6–2.4–2.2
68 B			115,800	67,500	18.5	44.6	269	39		
Average			120,100	67,750	17.5	40.8	262	36	2.7	2.4

creased hardness, strength and limit of proportionality with decrease in ductility, particularly as measured by reduction of area. Between 2 and 5 hours the changes in properties are negligible, there being evident principally a small decrease in strength.

In Fig. 10 are shown the structures of the steel under the treatments used and with increase in time at temperature there is more free cemen-

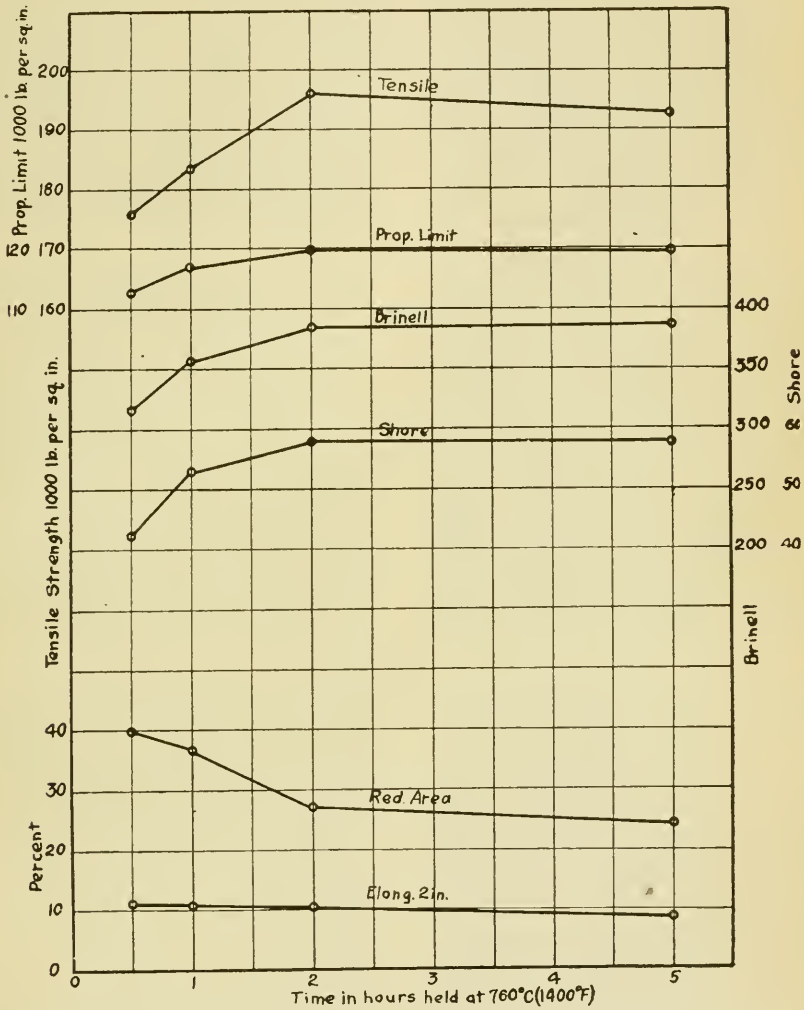

Fig. 9—Effect of time at 760 degrees Cent. on the mechanical properties of 1 per cent carbon steel subsequently oil quenched and tempered at 538 degrees Cent.

tite and the small globules of this constituent appear to combine to form larger ones as shown in Figs. 10*e* and 10*f*. While these changes are to be noted, a marked difference in the etching qualities of the ground mass is observed indicating that the structural changes accompanying the variations in tensile properties are partly due to changes in the condition of

the matrix. Specimens heated for various intervals and oil quenched without subsequent tempering were examined under the microscope and found to consist of troosto-sorbite and it appeared that the proportion of troostite was greater the longer the soaking.

When supplemented by Brinell hardness tests, the results of which are given in Table VII, it is evident that the effect of increasing the duration of heating for hardening results in a noticeable increase in hardness as does an increase in temperature.

To supplement available information and to correlate the tensile and impact properties of one heat of steel tempered at different temperatures after hardening in different ways, samples were tempered between 316 and 704 degrees Cent. (600 and 1300 degrees Fahr.) after quenching in oil or in water from just above or at the end of Ac_1 and in oil from a temperature slightly above the Acm transformation.

The results obtained in tests of steel quenched in water from 788 degrees Cent. (1450 degrees Fahr.) followed by tempering between 538 and 704 degrees Cent. (1000 and 1300 degrees Fahr.) are given in Fig. 11 and Table XIV and it is noted that the most rapid decrease in strength occurs when the tempering temperature is raised from about 538 to 649 degrees Cent. (1000 to 1200 degrees Fahr.) while at the same time the elongation is almost doubled and reduction of area materially increased.

The mechanical properties-tempering temperature curves shown in Fig. 12 are based on results given in Table XV for steel quenched in oil from 788 or 843 degrees Cent. (1450 or 1550 degrees Fahr.) and are of the same general type. Samples quenched at the highest temperature show the highest strength with lowest elongation and reduction of area throughout than those quenched from 788 degrees Cent. (1450 degrees Fahr.), or in other words, a higher tempering temperature is required when using the highest quenching temperature to produce a given strength.

By interpolation of the graphs giving variations in tensile properties of the tempered steel hardened in different ways, it is possible to compare the various treatments applied in order to produce a given strength and the results obtained from this approximation are given in Table VIII.

For the production of given strength by heat treatment a slightly higher tempering temperature is required after oil quenching from just above the Ac_1 transformation than when the steel is water quenched from the same temperature. Likewise a higher temperature is required when oil quenching from above the Acm transformation than when similarly cooled from just above Ac_1 in order to produce the same strength. In general this difference is less as the temperature at which the steel is tempered increases.

Water quenched steel subsequently tempered to show the same strength as that quenched in oil and tempered has a very much higher proportional limit than the latter and also greater hardness as measured by the Brinell and Shore methods. As the tempering temperature approaches the lower critical range these differences at first decrease and then slightly increase. While the difference between the hardness of water and oil quenched steels is well known, it is interesting to note the magnitude of this difference for the steel under consideration and the fact that it is maintained over a wide range of tempering.

In view of the slight difference in tensile properties between the

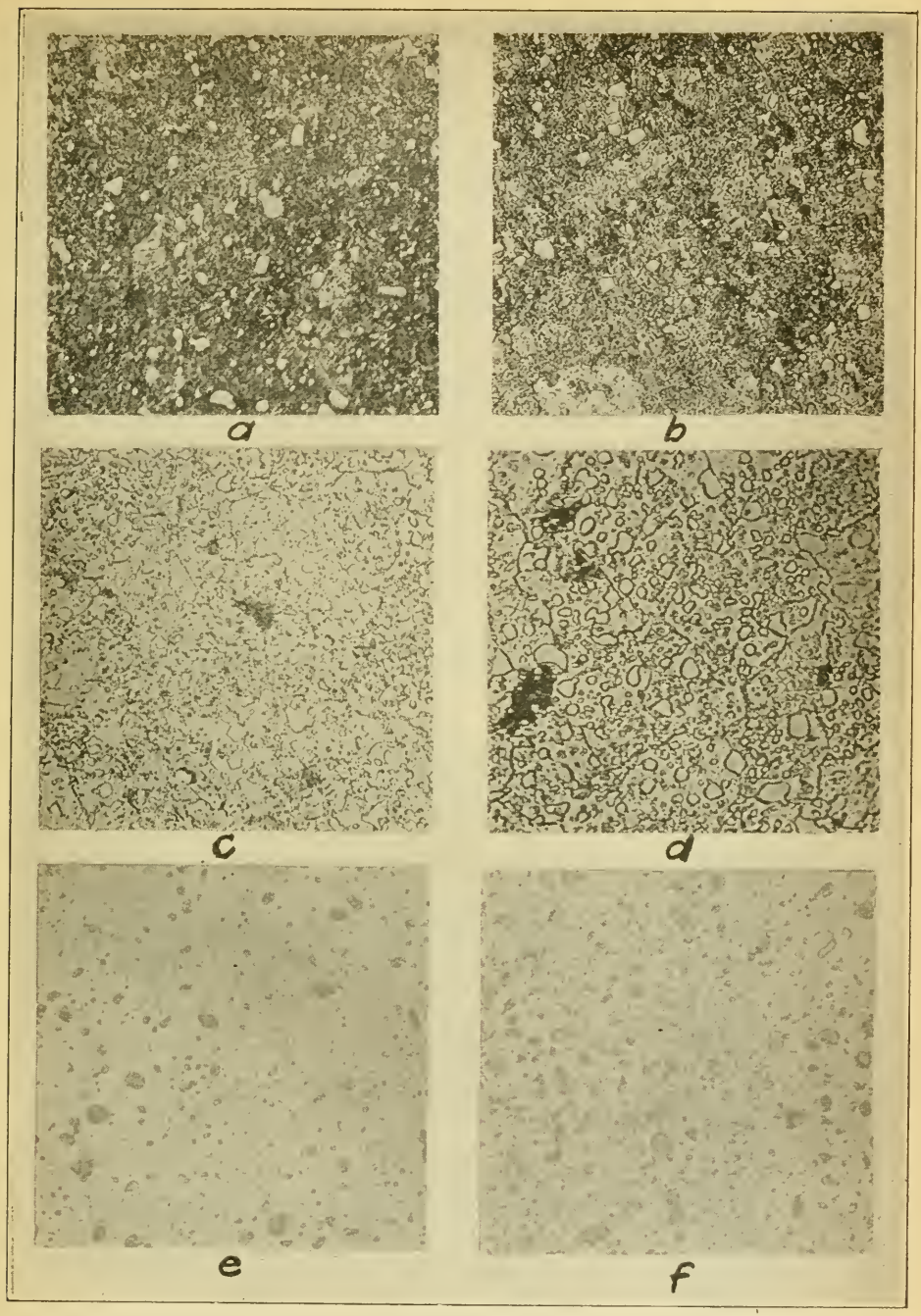

Fig. 10—Microstructure of 1 per cent carbon steel held at 760 degrees Cent. for various times and subsequently oil quenched and tempered at 538 degrees Cent. X 500. *a* held 30 minutes. *b* held 1 hour. *c* held 2 hours. *d* held 5 hours. *e* held 30 minutes. *f* held 5 hours. *a, b, c* and *d* etched in 2 per cent nitric acid in alcohol. *e* and *f* etched in boiling sodium picrate

Table XV

Effect of Tempering on the Mechanical Properties of 1 Per Cent Carbon Steel First Oil Quenched from 788 or 843 Degrees Cent.

Specimen No.	Held 30 minutes at temperature indicated and oil quenched Degrees Cent.	Degrees Fahr.	Tensile Strength Pounds per square inch	Proportional Limit Pounds per square inch	Elongation in 2 inches per cent	Reduction of Area per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed Foot Pound Charpy	Impact Energy Absorbed Foot Pound Izod
Steel heated for 30 minutes at 788 degrees Cent. (1450 degrees Fahr.) and oil quenched										
11 B	316	600	197,000	122,000	8.0	24.8	364	52	2.2–3.1–3.3	2.7–2.1–3.3
12 B			206,000	130,000	9.5	32.0	386	56	4.8–7.5–4.8	
Average			201,500	126,000	8.8	28.4	375	54	4.3	2.7
3 B	538	1000	188,250	110,500	....	....	340	48	3.0–3.5–2.3	2.0–2.0–3.0
4 B			169,000	113,000	13.0	39.3	318	48	3.9–3.9–4.8	
Average			178,600	111,750	....	....	329	48	3.5	2.3
13 B	649	1200	140,700	93,000	18.0	45.3	278	41	3.0–3.1–3.0	2.3–2.0–2.4
14 B			141,800	91,500	...	....	277	41	3.9–4.4–3.9	
Average			141,250	92,250	....	....	278	41	3.5	2.2
59 B	704	1300	115,800	72,500	20.0	49.8	235	36	2.8–2.1–2.2	3.5–3.7–4.0
16 B			117,800	82,000	21.0	47.6	241	36		2.6–2.1–2.1
Average			116,800	77,250	20.5	48.7	238	36	.0	3.0
17 B	760	1400	171,700	108,000	12.0	40.4	302	42		
18 B			171,600	110,000	11.5	42.3	286	40		
Average			171,650	109,000	11.7	41.3	294	41		
Steel heated for 30 minutes at 843 degrees Cent. (1550 degrees Fahr.) and oil quenched										
61 B	316	600	228,000	145,000	8.0	20.3	512	66	3.1–3.2–3.0	4.0–2.7–3.8
62 B			228,200	147,000	8.0	20.3	470	64	8.0–2.2	
Average			228,100	146,000	8.0	20.3	491	65	3.9	3.5
7 B	538	1000	199,000	121,000	10.5	29.5	364	53	3.1–3.3–3.1	3.1–3.2–3.1
8 B			185,000	119,000	11.5	29.5	387	54		
Average			192,000	120,000	11.0	29.5	376	54	3.2	3.1
22 B	649	1200	.....	90,500	17.5	45.6	277	42	3.9–4.8–4.8	3.5–3.5–3.5
63 B			144,700	98,500	15.0	41.0	290	42		
Average			144,700	94,500	16.2	43.3	284	42	4.5	3.5
23 B	704	1300	125,200	86,000	18.8	46.7	260	40	3.3–3.0	3.0–2.8–3.0
24 B			140,200	.....	17.0	40.2	248	40	9.6–6.6–4.8	4.5–5.5–6.0
Average			132,700	86,000	17.9	43.4	254	40	5.5	4.1
25 B	760	1400	186,800	117,500	11.0	38.1	319	45	3.1–2.9–3.0	2.8–2.7–3.0
26 B			170,000	108,000	11.5	41.6	332	40		
Average			178,400	112,750	11.2	39.8	326	43	3.0	2.8

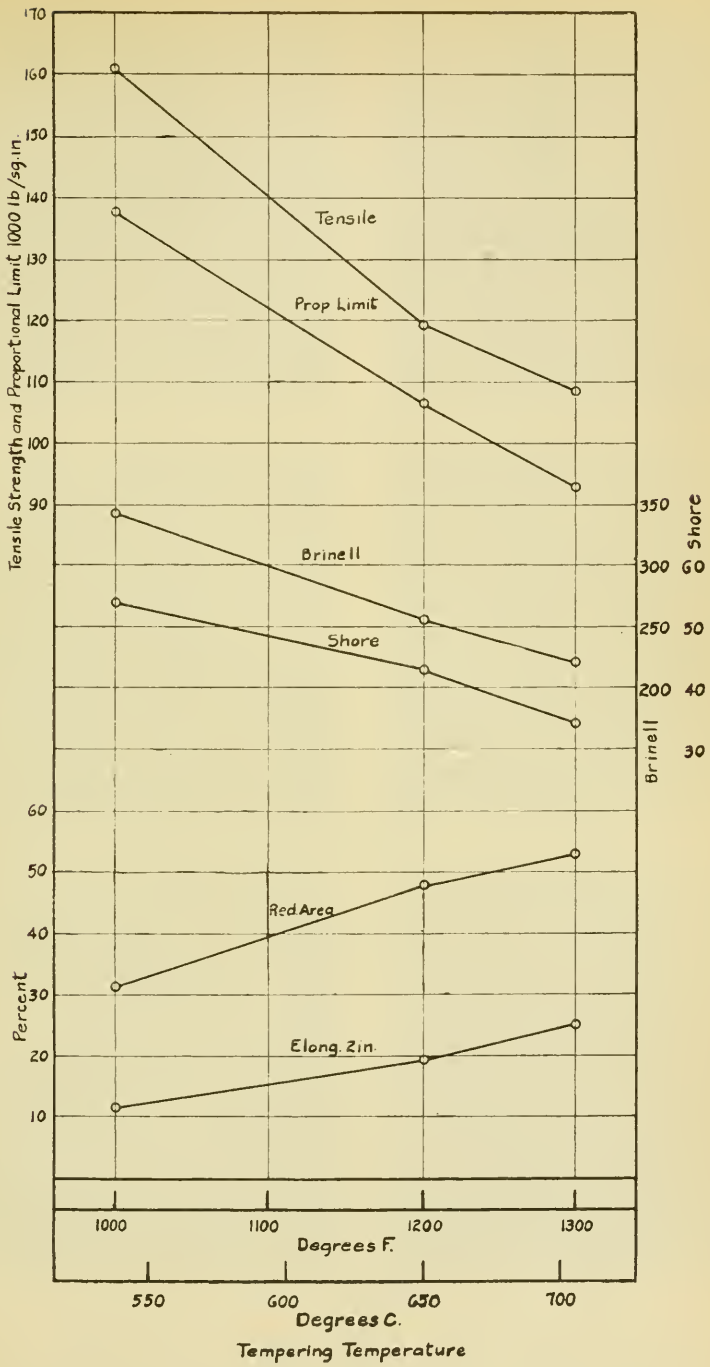

Fig. 11—Effect of tempering on the mechanical properties of 1 per cent carbon steel first quenched in water from 788 degrees Cent.

steel quenched in oil from 788 degrees Cent. (1450 degrees Fahr.) and that from 843 degrees Cent. (1550 degrees Fahr.) the lower temperature is recommended. If the excess carbide exists in plate form due to a previous high heating it may be refined readily by normalizing. A preliminary quench from above Acm, however, appears preferable. Water hardening is the best method, for the production of strengths in the neighborhood of 120,000 pounds square inch requiring a tempering of about 649 to 710 degrees Cent. (1200 to 1300 degrees Fahr.), providing always that the size and shape of the material is such as to allow the use of a drastic quenching medium.

The structures of samples subjected to the various tempering treat-

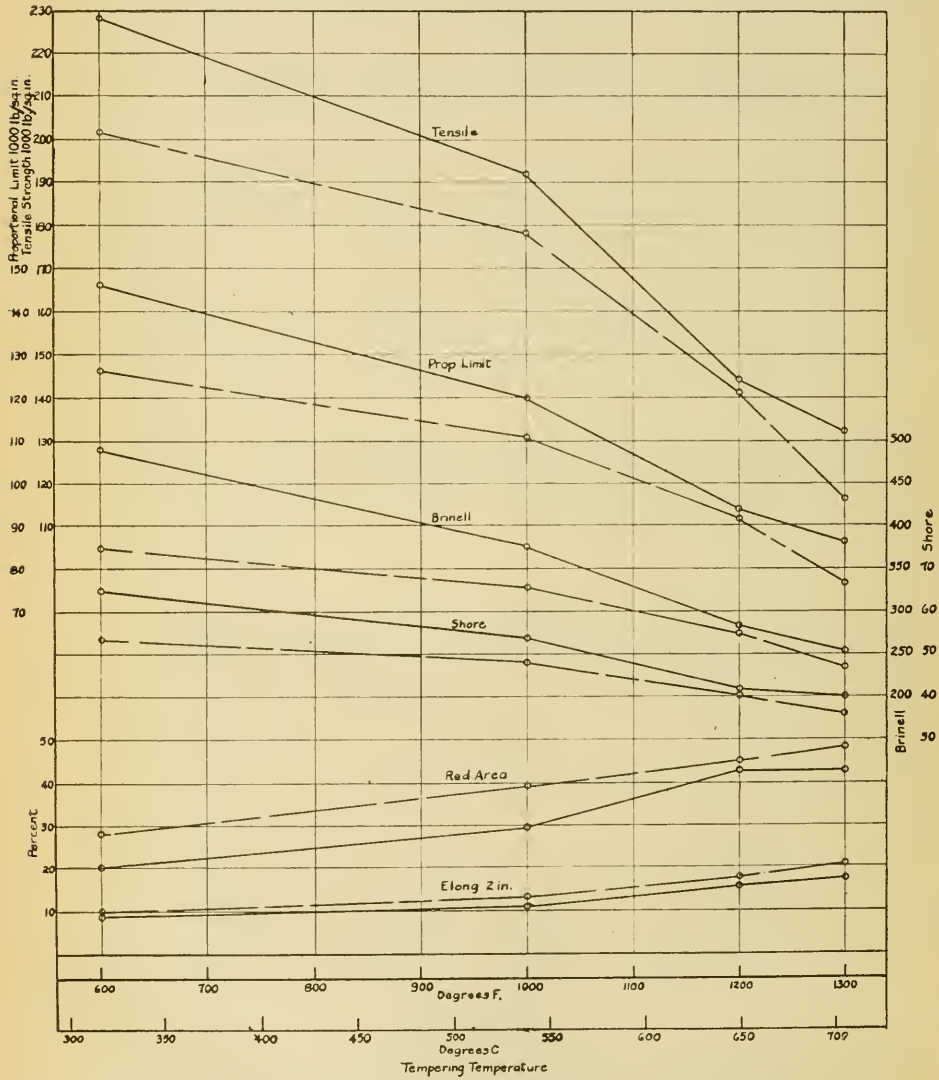

Fig. 12—Effect of tempering on the mechanical properties of 1 per cent carbon steel first oil quenched from either 788 or 843 degrees Cent.

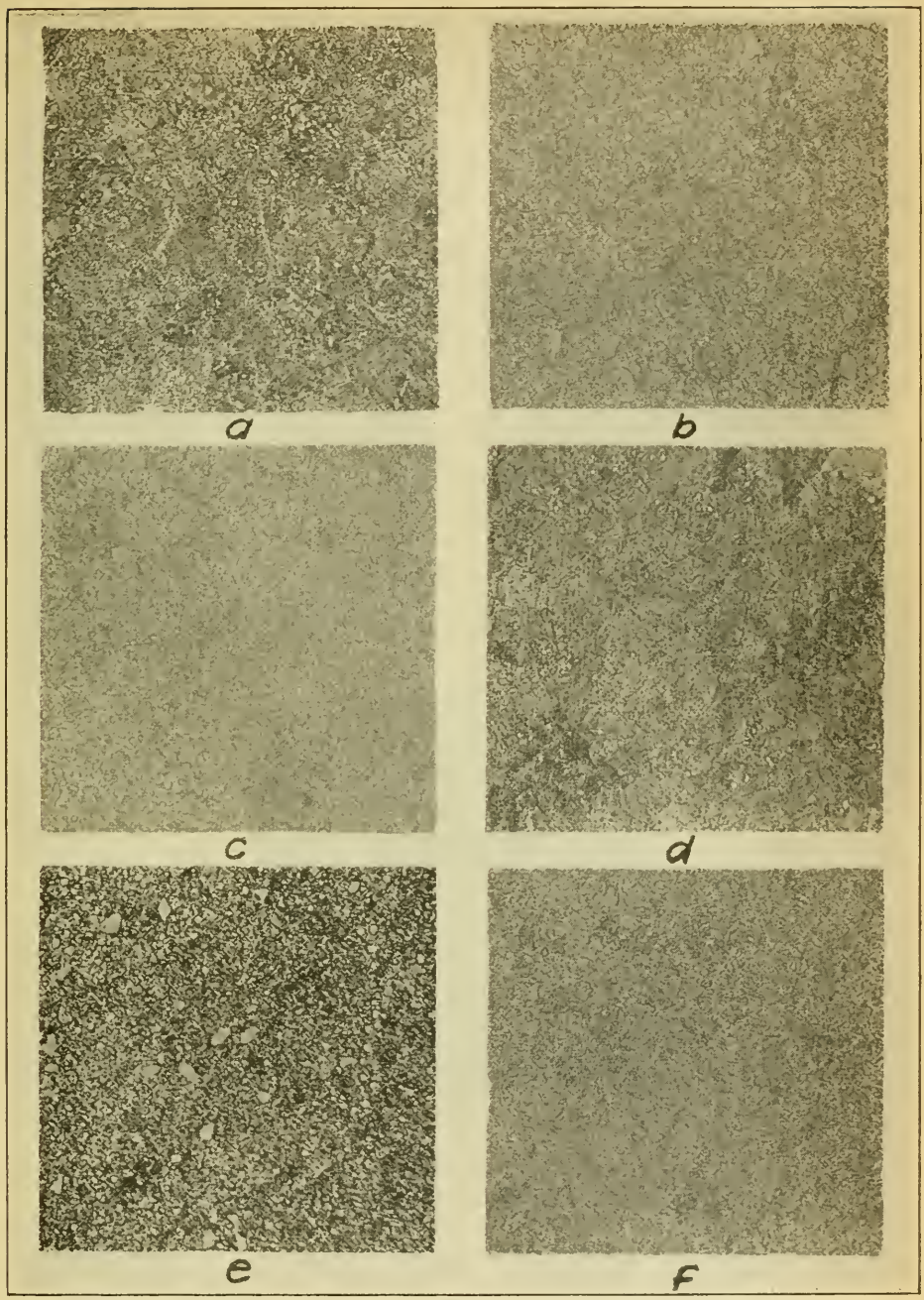

Fig. 13—Microstructure of 1 per cent carbon steel oil quenched from 788 or 843 degrees Cent. and subsequently tempered at different temperatures. Etched with 2 per cent nitric acid in alcohol and X 500. *a* quenched from 788 degrees Cent. and tempered at 316 degrees Cent. *b* quenched from 788 degrees Cent. and tempered at 649 degrees Cent. *c* quenched from 788 degrees Cent. and tempered at 704 degrees Cent. *d* quenched from 843 degrees Cent. and tempered at 316 degrees Cent. *e* quenched from 843 degrees Cent. and tempered at 649 degrees Cent. *f* quenched from 843 degrees Cent. and tempered at 704 degrees Cent.

ments are shown in Figs. 13 and 14 and are of the usual type. After short time tempering at 316 degrees Cent. (600 degrees Fahr.) the steel is troosto-sorbitic and as the tempering temperature increases there is a gradual transition of the ground mass to its more stable form. The water quenched steel, however, has the finest structure regardless of the tempering temperature used.

The effect of soaking at 704 degrees Cent. (1300 degrees Fahr.) when followed by quenching in oil, on the properties of oil hardened steel is shown in Fig. 15 and Table X. A change from ½ to 5 hours has re-

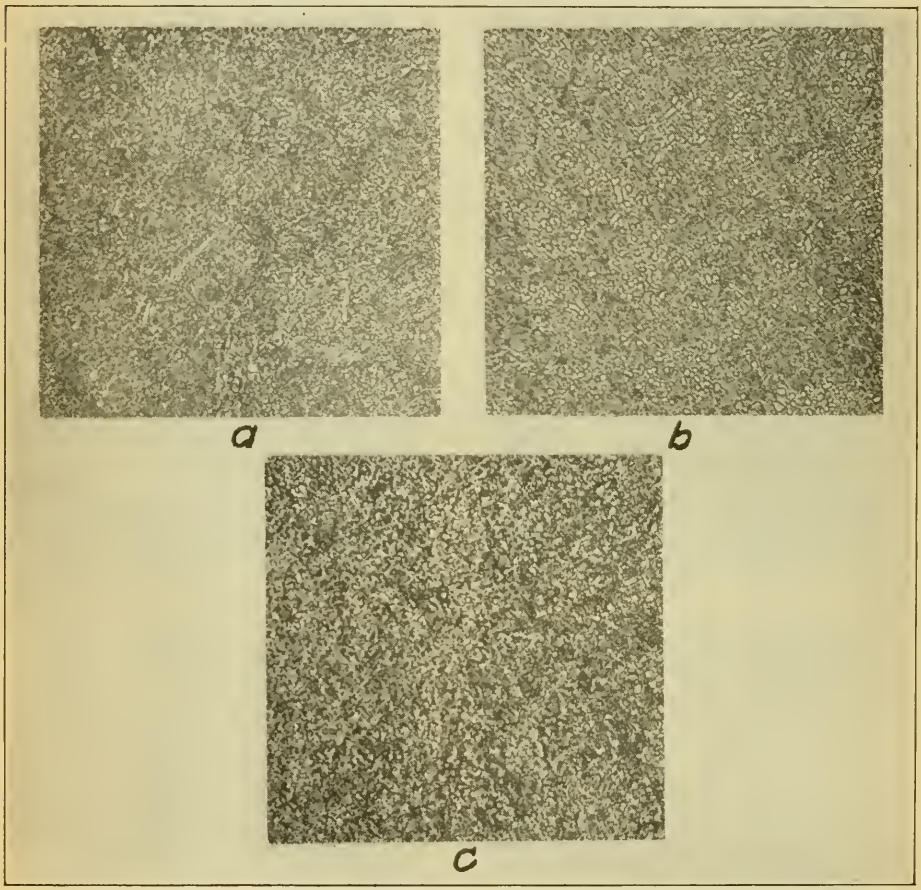

Fig. 14—Microstructure of 1 per cent carbon steel water quenched from 788 degrees Cent. and subsequently tempered at different temperatures. Etched with 2 per cent nitric acid in alcohol and X 500. *a* tempered at 538 degrees Cent. *b* tempered at 649 degrees Cent. *c* tempered at 704 degrees Cent.

duced the hardness considerably, the strength by about one-third and markedly increased the ductility. As shown in Fig. 16 there is very little change in the character of the excess carbide with increased heating time so that the change in properties is a result of a distinct softening of the matrix. Comparison of the tensile properties shown in Fig. 15 with results obtained on normalized steel at once shows the effectiveness of temperatures just under the lower transformation for softening this alloy.

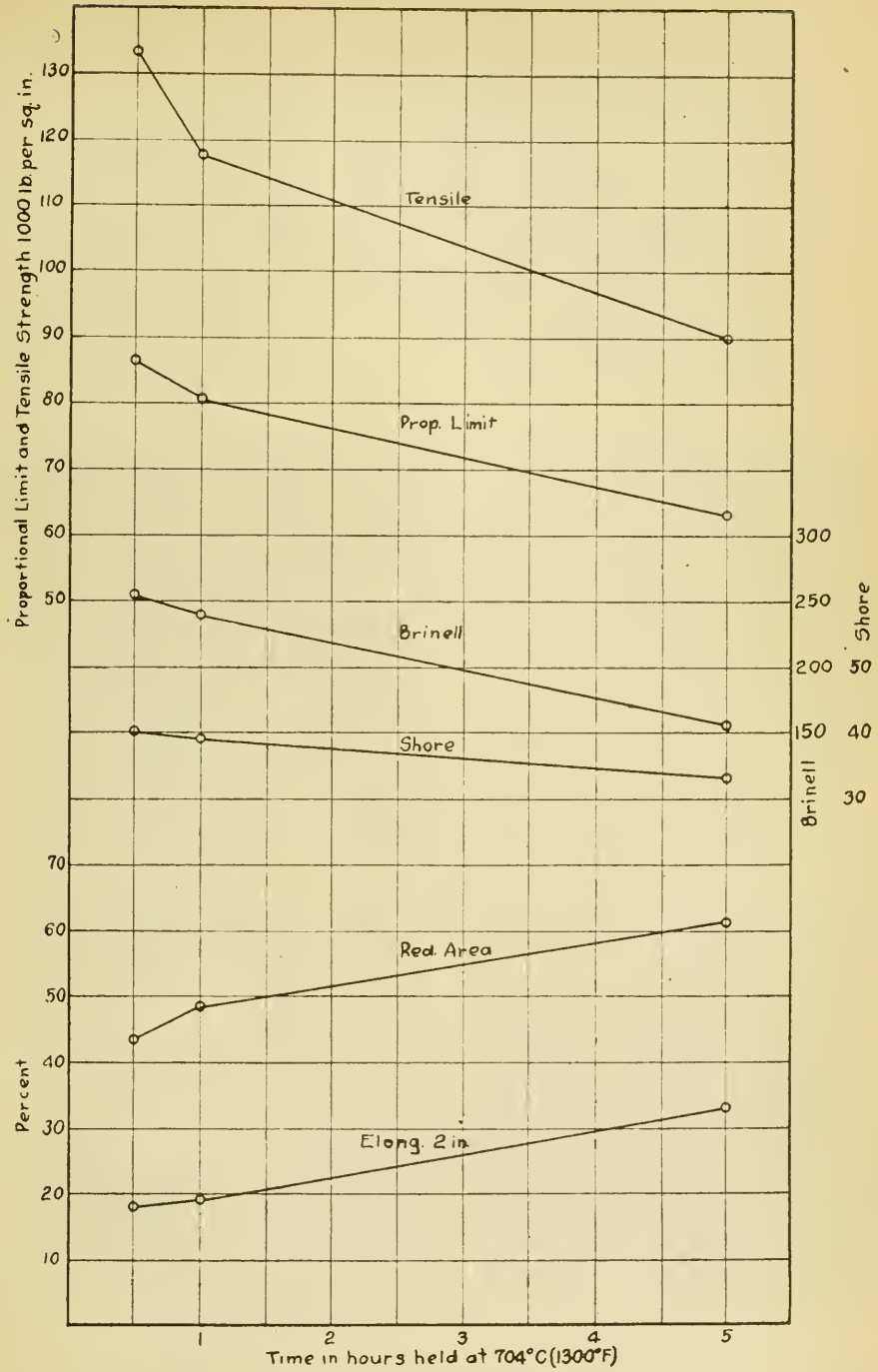

Fig. 15—Effect of time slightly below Ac_1 on the mechanical properties of 1 per cent carbon steel previously oil quenched from 843 degrees Cent. Samples oil quenched from the tempering temperature

As far as the tensile and impact properties of heat treated 1 per cent carbon steel are concerned, certain facts deserve emphasis in connection with the tests previously described. The steel remains extremely brittle even though good combinations of tensile strength and ductility are obtained by suitable treatment. Such low resistance to impact makes the surface condition of the metal of great importance, so that moderately sharp corners, and even scratches may greatly affect the behavior of the steel in service. It is extremely sensitive to heat treatment. Small changes in the hardening temperature produce large differences in tensile properties though after quenching in a given medium as in oil such differences may be largely removed by varying the tempering temperature.

To retail all excess cementite in solution when quenching in oil requires a relatively high temperature. The lowest temperature at which this may be brought about, among other factors, is dependent upon the time of heating prior to hardening, and is lower the longer the soaking but must be at or above the range of solution of this carbide. Between Ac_1 and Acm the excess cementite spheroidizes and coalesces to form larger globules which are retained in the free state in the oil quenched steel. At temperatures slightly below Ac_1 long time heating when fol lowed by cooling in oil produces no change in the condition of the cementite which may be observed readily under the microscope.

In this connection attention is directed to a recent study of the formation of spheroidal cementite by Honda and Saito[23]. The authors conclude that spheroidization of granular pearlite takes place below Ac_1 if held at temperature for a sufficiently long time but that the spheroidization of lamellar pearlite cannot proceed until Ac_1 has been reached or exceeded. If the maximum temperature in heating exceeds a certain limit above this transformation the cementite appears as a lamellar pearlite on cooling and therefore no spheroidization will take place.

The tests carried out in this investigation further indicate the importance of time at temperatures between Ac_1 and Acm as shown in Fig. 9. The sensitivity of 1 per cent carbon steel in this temperature range, within which it is ordinarily heated for hardening to varying time-temperature relations is great and the data obtained show why widely different results may be obtained so readily in the application of the heat treated product.

Based on the tests made under conditions previously described, the following conclusions are drawn:

1. The most suitable oil or water quenching temperature for steel which is subsequently to be tempered at relatively high temperatures is slightly above the end of the Ac_1 transformation.

2. With increase in oil quenching temperature for steel subsequently tempered at 538 degrees Cent. (1000 degrees Fahr.), hardness, strength and limit of proportionality increase and maximum values are obtained after quenching from 843 degrees Cent. (1550 degrees Fahr.) which is coincident with retention of all but a small portion of the excess cementite. A higher quenching temperature results in decreased strength.

3. When this steel is subsequently to be tempered to produce a tensile strength in the neighborhood of 120,000 pounds square inch water

[23] K. Honda and S. Saito, "On the Formation of Spheroidal Cementite." Journ. I. & S. Inst., 1920. Vol. 2, p. 261.

quenching is to be preferred on account of the higher elastic ratio produced, always assuming that the size and shape of material is such as to allow drastic treatment. If higher strength is desired, which condition requires lower tempering, oil quenching from just above the Ac_1 transformation will give slightly better combinations of strength and ductility but with lower elastic ratio than are obtained by water hardening.

4. A lower tempering temperature is required after water hardening than when cooling in oil from the same temperature in order to produce the same strength. This difference in temperature in general increases the higher the strength required, the lower the tempering temperatures.

5. When samples are quenched in water and others quenched in oil and all so tempered as to produce the same strength, the water quenched steel will have the highest hardness as determined by the Brinell and Shore methods.

6. While good combinations of tensile strength and ductility may

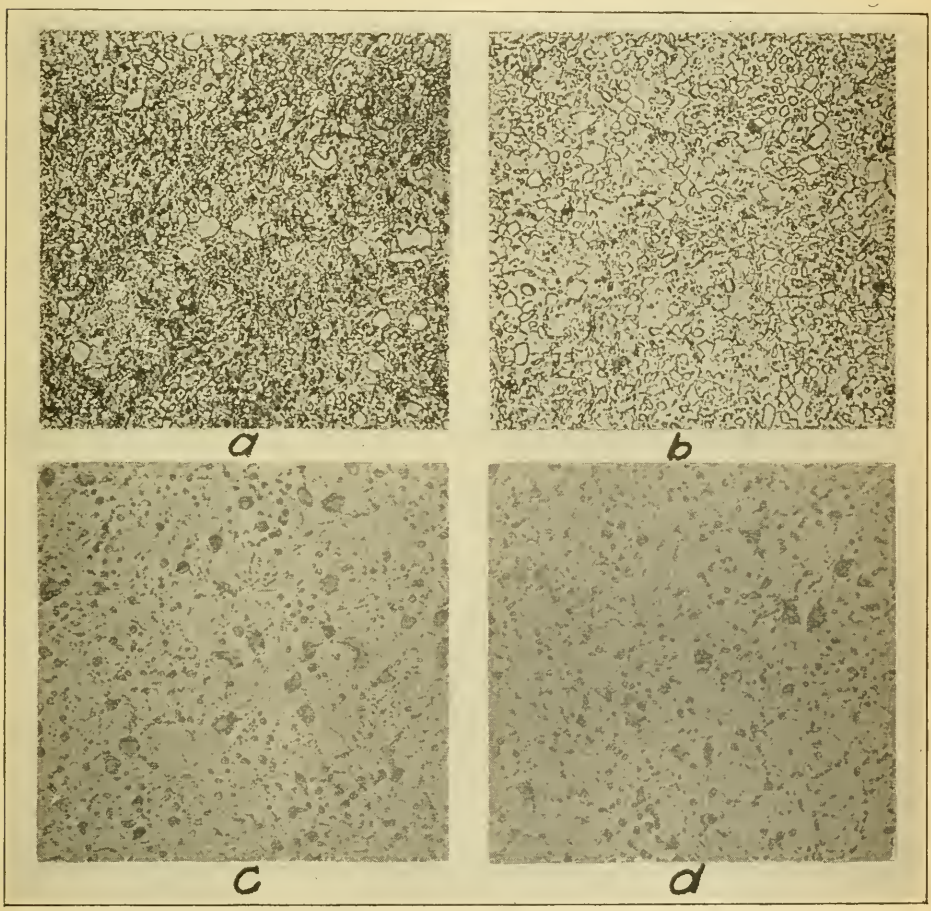

Fig. 16—Microstructure of 1 per cent carbon steel oil quenched from 843 degrees Cent. and subsequently tempered for various times at a temperature slightly below Ac_1. *a* tempered 1 hour. *b* tempered 5 hours. *c* tempered 1 hour. *d* tempered 5 hours. *a* and *b* etched with 2 per cent nitric acid in alcohol. *c* and *d* etched with boiling sodium picrate

be obtained by tempering at the higher tempering temperatures, the steel is brittle and has low resistance to impact. This is shown by the much higher combinations of strength and ductility obtained in tensile tests when the steel is ground to size after heat treatment and by the low Charpy and Izod values obtained in all cases.

7. Increased time at hardening temperatures results in increased hardness, strength and limit of proportionality and decreased ductility as does rise in temperature.

8. Long time heating just under the lower critical range results in a material softening of the steel, equivalent to a decrease of 40 per cent in Brinell hardness and 20 per cent in Shore hardness when the time at temperature is increased from 30 minutes to 5 hours. Short-time heating in this temperature range results in a softer steel than that air cooled from above the transformations.

9. The changes in physical properties which have been described are in all cases coincident with well defined structural changes.

In conclusion acknowledgement is made to T. E. Hamill, laboratory aid of the Bureau of Standards, for assistance in carrying out the various heat treatments and physical tests involved.

DO ALLOY CARBONIZING BOXES PAY?

By C. M. Campbell

THE prime reason for using an alloy carbonizing box is to save money. Any saving of time in handling, both in receiving stores and in the heat treating plant, and uniform quality of carbonizing are a saving of money. In the case of the alloy box this is accomplished by increasing its working life, as expressed in terms of furnace hours, over that of a cast iron or steel box of the same capacity in the same ratio as their unit prices.

Some types of alloy carbonizing boxes, however, work out better than a direct proportion; therefore, if the heat treating plant costs include figures based upon the performance of cast iron or steel boxes, additional savings are obtained. The unit price of alloy boxes is such as to be considered considerably out of line. Although they show long and efficient service, it is difficult to see just why they should not be placed on the supply account instead of becoming a part of the equipment.

Several reasons may be given for this attitude, but before discussing them, we will consider some of the factors governing the life and performance of carbonizing boxes. They may be summed up as follows:

1. Critical points at or below average atmospheric temperatures.
2. Low coefficient of expansion and contraction at high temperatures.
3. Good elastic limit and ductility at high temperatures.
4. Tendency to resist carbon absorption up to and including temperatures of carbonization of steel.
5. Resistance to oxidation.

Resistance to warping and cracking seems to depend largely upon the first two factors mentioned and is independent of the shape of the box. It may be considered also that lack of grain growth is important here. Good heat conductivity is important, but it is characteristic of metals having high coefficient of expansion. The alloy which seems to possess most of these features is one having a nickel base with some chromium and iron.

Several attempts are being made to produce alloys of iron and chromium, an iron base with chromium and silicon 1.5 to 3.5 per cent, the idea being to produce a medium priced box. These alloys resist oxidation as good as nickel-chromium-iron alloys but they will crack at from 600 to 1200 furnace hours, while the alloy which meets the five conditions mentioned above, stands up 3000 furnace hours and better, depending upon the size and shape of the box.

An iron-chromium-silicon alloy which analyzes: Carbon over 0.50, chromium 15.00, and silicon 3.00 per cent show the following properties in the cast condition:

Elastic limit, pounds square inch	45,000-50,000
Ultimate strength, pounds per square inch	53,000-55,000
Elongation in 2 inches, per cent	1.00
Reduction of area, per cent.	2.00
Coefficient of linear expansion, 32 to 212 degrees Fahr	0.0000089
Scleroscope hardness	30-34
Brinell hardness at 3000 kilograms	179-207

A paper presented at the Indianapolis Convention. The author, C. M. Campbell, is superintendent, Pioneer Alloy Products Co., Cleveland.

Ratio of scleroscope hardness to Brinell hardness	5.42-6.90
Scleroscope hardness after heating to 1800 degrees Fahr. and air cooling	40-45
Brinell hardness after heating to 1800 degrees Fahr. and air cooling	364
Ratio of scleroscope hardness to Brinell hardness, specimens heated to 1800 degrees Fahr. and air cooled	9.1-8.56

This material has some toughness as shown by the scleroscope and Brinell hardness but when heated to 1800 degrees Fahr. and air cooled it loses its toughness and becomes brittle. As a result the carbonizing boxes crack.

In practice, using a square carbonizing box weighing 55 pounds, having a uniform wall thickness of ⅜-inch and round corners with ⅝-inch radius, resistance to oxidation, warping and cracking is good up to 400 furnace hours. Beyond that time cracking takes place, and a slight warping in the bottom of the box is noticed; this occurring usually around 600 furnace hours. In all instances of cracking, one crack appears down the side of the box. In some cases, this starts as a surface crack and gradually works through the wall in 600 to 1100 furnace hours.

In one case out of eight, the carbonizing box was used 1400 furnace hours and showed no signs of scaling and cracking, but slight warping occurred in the bottom. When heated to 2200 degrees Fahr. and furnace cooled, a box showed a scleroscope hardness of 20 and a Brinell hardness of 149, the ratio being 7.45. When reheated to 1800 degrees Fahr. and air cooled, it showed a scleroscope hardness of 15 and a Brinell hardness of 143 with a ratio of 9.53. No decrease in hardness was shown but brittleness increased. Cooling from 2200 degrees Fahr. forms a solid solution structure which is not produced at temperatures under 2000 degrees Fahr., the metal being in the cast condition. This iron-chrome-silicon alloy can be cast in either green or dry silica sand molds when the carbon content is less than 0.25 per cent.

It seems to be on account of the relatively high price of such an alloy that objections to its widespread use is based. These objections have their origin in the kind and amount of material being carbonized and as to whether the business is jobbing or specialty, and if the latter, whether the heat treated work is of one kind or diversified. The jobbing shop will carbonize a variety of steel parts on numerous small and large orders. Thus it is necessary to have on hand several different sizes of boxes, many of which are in use only at long intervals. It would seem, in this case, that a stock of high priced carbonizing boxes would unduly burden equipment and depreciation accounts.

In cases where the shop will have large orders for one or more different kinds of articles, it may be decided to charge the cost of the alloy boxes to be used against each order. For example on an order for a quantity of case hardened bolts, it is found that the required number of carbonizing boxes at 10 cents per pound will add ¼ cent to the cost of each bolt. If the box cost $1.25 per pound, it will raise the cost on each bolt to some 3 cents. If the value of the bolts is small and competition keen, such a price may be out of the question. Here, the most important factors to be considered are: The value of the product, and strength and amount of competition.

The conditions in a specialty shop are quite different from those prevailing in a jobbing shop. In this case, the amount and value of each kind of article to be carbonized is known in advance and, although the

charge per furnace hour varies with the size of the boxes, an increase in their life decreases the charge per furnace hour as shown by the following figures:

Weight of box pounds	Price per pound	Total cost	Furnace hour charge	Furnace hour life
45	$1.25	$56.25	0.938c	6000
45	1.25	56.25	0.803	7000
45	0.40	18.00	1.500	1200
45	0.40	18.00	1.285	1400
45	0.40	18.00	0.900	2000
45	0.10	4.50	1.125	400
45	0.10	4.50	1.000	450

Now suppose we take a box weighing 50 pounds and it is shown that its life is 6000 furnace hours. The initial investment will be some $56.00, and the furnace hour minimum being 6000, the charge per furnace hour will be 0.93 cents. If you should get 7000 hours out of that, the price would drop to 0.80 cents. If you were using at the same time for that same class of work, and on that same class of order, a 45-pound box, which costs 10 cents a pound, the initial investment is $4.50, and the charge per furnace hour would be 1.125 cents. If you should get 450 furnace hours, it would drop to 1.00 cent. Now if you use the alloy just described, the iron-chrome-silicon, which may sell at this time for some 40 cents per pound, you would have an initial investment of $18.00. But the best we can do, perhaps, out of that is 1200 furnace hours, so it would cost 1.50 cents per furnace hour. If that increases to 1400 furnace hours, it would bring it to 1.285 cents, and if you should by any chance go to 2000 furnace hours, it would drop to 0.90 cents.

The value and amount of a given article affect the kind of carbonizing box to use. For a given kind of carbonizing box a decreasing value of the article increases the number to be carbonized in order to pay for the box, as shown as follows:

Unit charge	Cost of box	Number of pieces
00.75c	$10.00	1333
00.50	$10.00	2000
00.25	$10.00	4000

The selling price of the product usually includes a large enough gross profit to make possible the addition of a fraction of a cent or a few cents to the production cost of the article, or the addition of another item to equipment and depreciation costs without decreasing net profits, because these additional charges are offset by economies in other directions due to the use of the alloy box. When these charges are more than offset, the difference is an addition to net profits. Owing to the conditions in the jobbing shop, which prohibit the extensive use of alloy boxes, it has been suggested that such boxes be sold on the basis of service.

Now it would seem that if you would charge on a basis of service, you carry that out, for instance, like the United Shoe Machinery Co.'s, which rent shoe machinery to individuals. It makes possible the use of shoe machines even in the small repair shops. But the same applied to carbonizing boxes would require service stations located at points such as Pittsburgh, Cleveland, Indianapolis, Chicago and other points, and a warehouse carrying in stock a large number of different size boxes, this stock being determined in advance by a study of the requirements of

those neighborhoods. When an operator wished to have a box for his plant, he would call up the service station and get the required number. If he had an order for a certain number of articles and he had no boxes; he would know from that order about what size boxes he needed, how many, and the length of time required to carbonize the work, and he would know in advance the charge for the service. He could add that on to the cost of carbonizing and would know in advance just what his total costs would be. If he did not need the boxes for further work, he could send them back to the service station. However, that service charge will have to include the cost of boxes in stock at the service station, and that might run pretty high. In addition, the fact that it is fundamental in all businesses that you have to have a large enough gross profit in order to establish the business in a given locality, one could not say at this time just what it would cost for service on that basis.

It is also seen here from the conditions outlined in the tables, that with a study of the subject of costs along that line, each individual heat treater or each manager of a heat treating plant, could apply these tables in his own plant. The writer knows of two different plants manufacturing substantially the same kind of parts, operating on practically the same monthly capacity of parts in their heat treating plants. One operates in such a manner that a hard cast iron box will last an average of 150 hours on carbonizing, for example on cam shafts, the nickel-chrome alloy box will last not over 1800 furnace hours. In the other plant, which does a similar line of work, a hard cast iron box lasts better than 400 furnace hours, and the nickel-chrome alloy box lasts something over 2000 furnace hours. Both plants operate with the same kind of heat treating equipment.

From these tables it will be seen that the plant which has the lowest rate or lowest furnace hour life for its carbonizing boxes could use for carbonizing cam shafts a nickel-chrome alloy box, on which the price is of course high, but money could be saved because the cost per furnace hour is greatly reduced over that of hard iron boxes.

Discussion of Mr. Campbell's Paper

MR. PORTER: Can the alloy box be made as light as a hard cast iron box? My reason for asking that is that in one particular case a man has to pick up the box from the floor, put it on a bench, pack it and shift it on to a truck. He has no time to use mechanical equipment to do it. The alloy box that I bought weighs 75 pounds, as against 40 for the hard cast iron box.

MR. CAMPBELL: These alloy boxes can be made lighter than the hard iron box. The reason for that is that the physical properties of the nickel-chrome alloy are somewhat different from those of the iron. The hard cast iron, so-called, is brittle and thin sections seem to crack. Foundry practice, at the present time at least does not permit you to get the same thin sections with cast iron as you would with the nickel-chrome alloy, for the reason that you have a high expansion and high liquid contraction of cast iron, and unless you use a shell core, that is, a core made with a hollow center and very thin wall, it will be found almost impossible to get the same thin section that you can with the

nickel-chrome alloy. A box that weighs some 70 pounds in cast iron, can be made to weigh about 55 pounds, when cast with alloys.

MR. GORDON: You spoke about having the same condition in the two plants and getting a different life of the pots. Was that due to cracking or due to scaling or what seemed to be the cause of that? Was it a difference in the kind of fuel they were using or difference in regulation of the heat, or what?

MR. CAMPBELL: They didn't have the same conditions in the two plants. The policy of the management of one plant seemed to be to rush things through rapidly. This rushing process seemed to decrease the unit cost of manufacturing the article. However, the principal reason was, I think, that the article that they were making, the assembled article, was somewhat lower in cost than the article manufactured by the company that ran their plant cheaper on carbonizing boxes. As to warping and cracking, the conditions that cause warping and cracking are the same in all plants, but in this particular case where the work was rushed through, the warping and cracking occurred quicker than it would in the other plant.

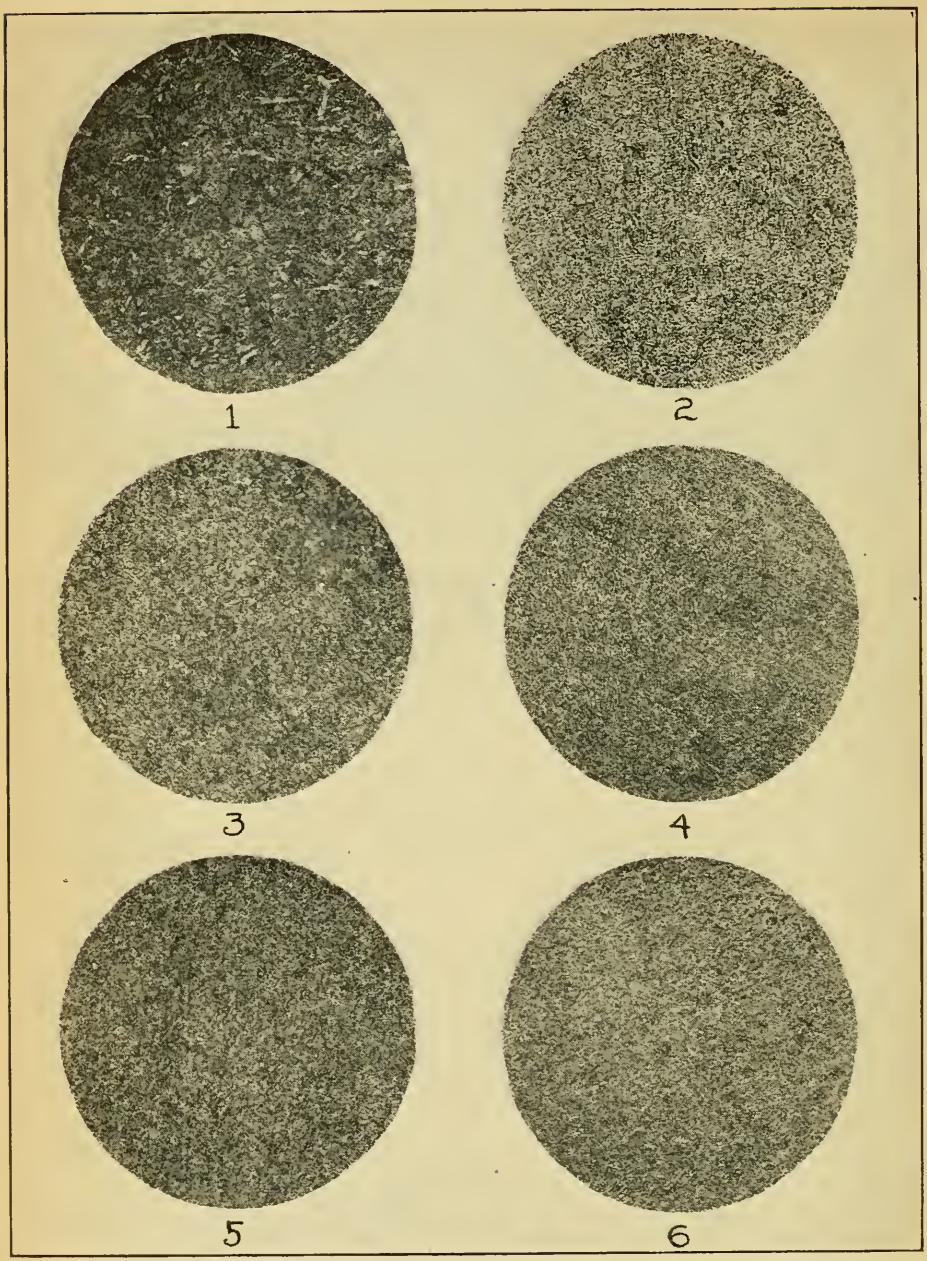

Fig. 1—Composition 254, nickel-silicon steel. Fig. 2—Composition 389 steel. Fig. 1 presents quite a contrast to Fig. 2, the latter being a more uniform steel and extremely well knit together in the arrangement of its constituent alloys. Fig. 3—Composition 390, reveals the structure when the nickel is doubled and the silicon increased 30 per cent. Fig. 4—Composition 530-1, shows the structure obtained by reducing the silicon one-half. Fig. 5—Composition 531-1, modified by zirconium. Fig. 6—Composition 532-1, containing titanium as stated

SOME ALLOY STEELS OF HIGH ELASTIC LIMIT, THEIR HEAT TREATMENT AND MICROSTRUCTURE

By Charles M. Johnston

AN INVESTIGATION was begun during the late European war for the purpose of developing the best light armor plate for the protection of gunners and airplane pilots. The best steel for the light plates, that is 0.2 to 0.5-inch thick, and probably the best steel of its kind at that time, was silico-nickel steel of 0.35 to 0.60 per cent carbon.

The demand arose for a still better steel to withstand increased striking velocity. Also ammunition charges were increased and types of cartridges of greater penetration were used. With a view to meeting these increased requirements as far as possible with silico-nickel steel as the fundamental composition, the effect of modifying this basic analysis by the addition of vanadium and chromium was tried. This addition of vanadium and chromium is now patented. The best heat treatment of the silico-nickel steel gave about 274,000 pounds per square inch, ultimate strength, 237,000 pounds per square inch, yield point, 11½ per cent elongation, 36 per cent reduction, and a 555 Brinell.

But upon the addition of chromium and vanadium, an ultimate strength of 290,000 to 310,000 pounds per square inch, 260,000 to 280,000 pounds per square inch yield point and 6 to 10 per cent elongation were obtained, with a Brinell hardness of 512. These good figures were reflected by improved showing in ballistic tests. As a result of experience gained during the war, the military authorities, especially for protection of air pilots, made requests for still greater strength in plates. This caused further experimenting until finally the silico-nickel composition was modified by increased amounts of chromium and vanadium and also by the addition of tungsten, zirconium, titanium and molybdenum in various combinations. It is not the purpose of this brief article to dwell on the ballistics obtained except to state that among the various compositions, about the best ballistics were secured from ¼-inch plates highly alloyed—one of the silico-nickel types containing molybdenum.

It should be said that the molybdenum content was so much overshadowed by the percentage of the other nonferrous elements that it cannot be assumed that the molybdenum was the cause of the improved showing. Of course the disciples of molybdenum will agree that it is most likely the master alloy in this case. For their further encouragement, the composition known as 491 can be considered as practically as good as the 490. It contained one-half as much molybdenum as 490.

The following are the best tensiles obtained from compositions 490 and 491:

	Composition		
	490	491	491
Quench (Oil), degrees Fahr.	1600	1600	1600
Draw, degrees Fahr.	1000 (½ hour)	1200 (1 hour)	1000 (½ hour)
Ultimate strength, pounds per square inch	276,260	193,910	275,000
Yield point, pounds per square inch	253,450	153,330	213,780
Elongation in 2 inches, per cent	Nil	12.5	2.5
Reduction in area, per cent	2.2	33.1	Nil
Brinell hardness	512	418	477

A paper presented at the Indianapolis Convention. The author, Charles M. Johnson, is director of research department, Crucible Steel Co. of America, Pittsburgh.

Also a composition known as 389 gave the following:

	Composition 389	
Quench, degrees Fahr.	1600	1600 (in oil)
Draw, degrees Fahr.	1000 (½ hour)	1200 (½ hour)
Ultimate strength, pounds per square inch	293,180	167,830
Yield point, pounds per square inch	280,110	157,780
Elongation in 2 inches, per cent	10.0	17.0
Reduction in area, per cent	31.5	47.5

Compositions 389 are splendid looking tensile strength specimens, showing three-quarters to complete cup, tough fracture and having 10 per cent elongation, even at 555 Brinell hardness. The foregoing yield points were taken with dividers and were from plate tests. These results from compositions 389, 490 and 491 suggested that a series of tests be made with rolled bars, 1 to 1½-inch rounds. The bars for this purpose were 389 composition, also the latter composition in which the silicon was increased 20 per cent and the nickel doubled (390-3), an ingot in which the silicon was reduced 50 per cent (530), one in which the silicon was reduced 50 per cent and about 1 per cent zirconium added to this reduced silicon (531), one in which the silicon was decreased two-thirds and 1 per cent of titanium added (532-1), one in which the silicon was reduced two-thirds and 0.6 per cent of titanium added (532-2), one in which the silicon was reduced two-thirds and less than 1 per cent of molybdenum added (534-1) and one in which the silicon was reduced two-thirds and less than 1 per cent of tungsten added (535-1).

The tabulations in Table I show the results of heat treating these steels. The test specimens were heat treated in 0.505-inch section and held at quenching temperatures 20 minutes after reaching the temperature of the furnace. The section was taken from the central portion of the bar. No record is given here of the various treatments used and physical properties, except those that were found to give elongations ranging from 5 to 10 per cent, consequently the tabulations are brief and do not reveal a considerable quantity of work done to arrive at the figures.

From the results in Table I, the following deductions can be made: First, that there is no apparent improvement in physical strength, at least as revealed by the tensile machine, by doubling the nickel content as shown by composition 390 compared with 389. Second, the table shows that the 389 composition is markedly superior to the 254 which is the well known silico-nickel composition.

Table II shows values obtained from zirconium and titanium steels. It does not reveal any superiority over the 389 steel which is a cheaper composition.

The results in Table III are especially interesting in that they are from two steels that are with the exception of one element, as much alike analytically as two peas in a pod, that is two peas that are alike. Anyone who has shelled peas knows that two peas in the same pod may be alike in complexion and general contour but not necessarily in size. These compositions, to be exact, are alike, but with the exception that one steel contains 0.7 per cent of molybdenum and the other contains 0.7 per cent of tungsten, with 389—silicon reduced two-thirds—as the basic composition. The molybdenum steel is 534-1, the tungsten steel is 535-1.

There is no marked difference in the physicals except perhaps elonga-

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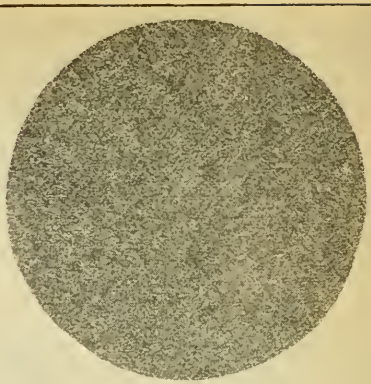
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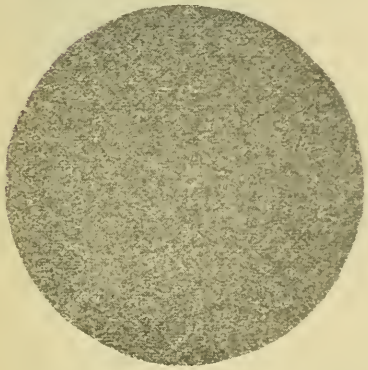
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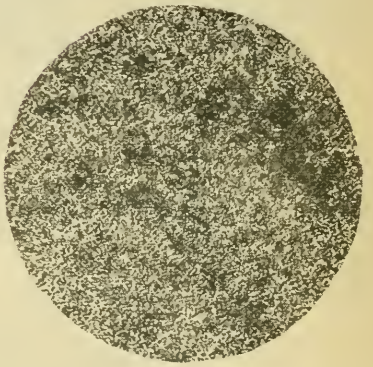
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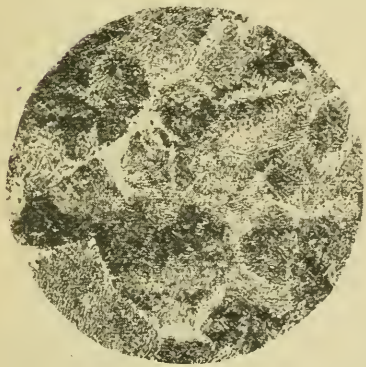
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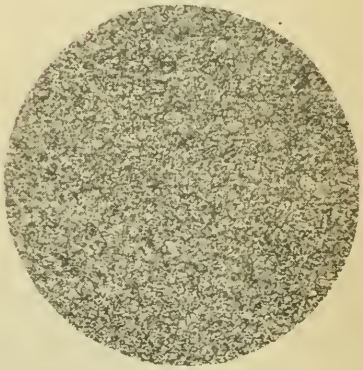
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Fig. 7—Composition 532-2, containing titanium as stated. The structures of compositions 390, 530-1, 531-1, 532-1, and 532-2 present marked similarity and microstructure. Fig. 8—Composition 534, of molybdenum content. Fig. 9—Composition 535, of tungsten content. The molybdenum and tungsten steels are referred to as being practically alike in composition, except in the items of molybdenum and tungsten. The microstructures of Figs. 8 and 9 apparently are almost identical in the heat treated state. Fig. 10—Composition 389 annealed. Elastic limit, 109,010 pounds per square inch; ultimate strength 144,450 pounds per square inch; elongation 17.5 per cent; reduction in area 29.7 per cent; fracture flat; Brinell 286. Fig. 11—Composition 254 annealed. Elastic limit 90,950 pounds per square inch; ultimate strength 136,900 pounds per square inch; elongation 3.5 per cent; reduction in area 4.7 per cent; fracture flat; Brinell 321. Both the photomicrographs and tensile figures demonstrate superiority of composition 389 over the 254 in annealed state as well as in hardened and drawn state. Fig. 12—Microstructure of high speed type of high elastic limit that falls into this class on account of its high elastic limit and good elongation

tion and reduction are a little better in the molybdenum steel. The molybdenum steel also has the advantage that it can be made in the open-hearth furnace, whereas the tungsten steel must be made either in the electric or crucible furnace. It is rather surprising that there is so little difference in the values, at least as revealed by the tensile machine.

A further investigation is planned to test these two steels for their torsional, impact, bending qualities, and for modulus of elasticity, etc.

Table I
Results of Heat Treating Various Steels

	Composition					
	254	254	389	389A	390	390
Quench (Oil), degrees Fahr.	1450	1600	1600	1550	1600	1550
Draw (1 hour), degrees Fahr.	1750	800	650	600	600	600
Elastic limit, pounds per square inch	231,700	231,950	249,500	247,770	233,000	226,400
Yield point, pounds per square inch	241,570	237,100	259,160	257,700	243,000	231,500
Ultimate strength pounds per square inch	255,660	274,740	311,690	308,900	295,900	291,400
Elongation in 2 inches, per cent	5.5	11.0	11.0	11.0	11.0	10.5
Reduction in area, per cent	23.2	36.8	42.9	39.5	27.2	26.9
Fracture	¾ Cup	¾ Cup	¾ Cup	Full Cup	¾ Cup	½ Cup
Brinell hardness	512	555	555	555	555	555

Table II
Test Values from Zirconium and Titanium Steels

	Composition				
	531-1Zr	532-1Ti	532-2Ti	530-1	530-1
Quench (Oil), degrees Fahr.	1550	1600	1600	1600	1550
Draw (1 hour), degrees Fahr.	750	600	600	600	750
Elastic limit, pounds per square inch	258,700	241,300	218,000	270,440	277,500
Yield point, pounds per square inch	263,800	256,200	232,000	280,000	282,450
Ultimate strength, pounds per square inch	306,900	280,950	265,300	330,550	308,200
Elongation in 2 inches, per cent	8.0	8.5	9.0	5.0	6.0
Reduction in area, per cent	28.4	29.7	37.7	10.4	19.4
Fracture	¾ Cup	½ Cup	Full Cup	Flat Break	¾ Cup
Brinell hardness	555	477	477B	555	555

Table III
Test Values from Molybdenum and Tungsten Steels

	Composition			
	534 Mo.	534 Mo.	535 W.	535W.
Quench (Oil), degrees Fahr.	1600	1650	1600	1650
Draw (1 hour), degrees Fahr.	650	650	650	650
Elastic limit, pounds per square inch	222,650	212,650	218,660	220,370
Yield point, pounds per square inch	227,480	217,810	223,510	225,270
Ultimate strength, pounds per square inch	269,360	270,570	265,790	270,560
Elongation in 2 inches, per cent	10.5	12.5	10.5	10.5
Reduction in area, per cent	42.8	45.1	41.4	40.0
Fracture	Full Cup	¾ Cup	¾ Cup	Full Cup
Brinell hardness	512	512	2	512 51

Also it will be an interesting study to determine at what point a gradual equal increasing of molybdenum on one hand and tungsten on the other would begin to show marked differences in the tensile and other physical properties and microstructure of these two types of steel.

A tungsten-chromium-vanadium steel that has been giving most excellent service in the trade for a number of years is interesting in this connection, in that it shows similar good physical values and yet is of a high speed type of analysis. The physicals are shown in the following tabulation:

Quench (Oil), degrees Fahr.	2200
Draw (1 hour), degrees Fahr.	1100
Elastic Limit, pounds per square inch	223,690
Yield point, pounds per square inch	245,820
Ultimate strength, pounds per square inch	256,630
Elongation in 2 inches, per cent	8.5
Reduction in area, per cent	26.8
Fracture	½ Cup
Brinell hardness	477

This well tried steel can be consistently classed in high elastic range with 9 to 10 per cent stretch.

The steels discussed in this article anneal best by being held at temperatures ranging from 700 to 740 degrees Cent. (1292 to 1364 degrees Fahr.) after normalizing at 900 degrees Cent. (1650 degrees Fahr.). Hardening ranges are shown by the tables from 1500 to 1650 degrees Fahr. for compositions 389, 390, 530, 531, 532 and 534, and

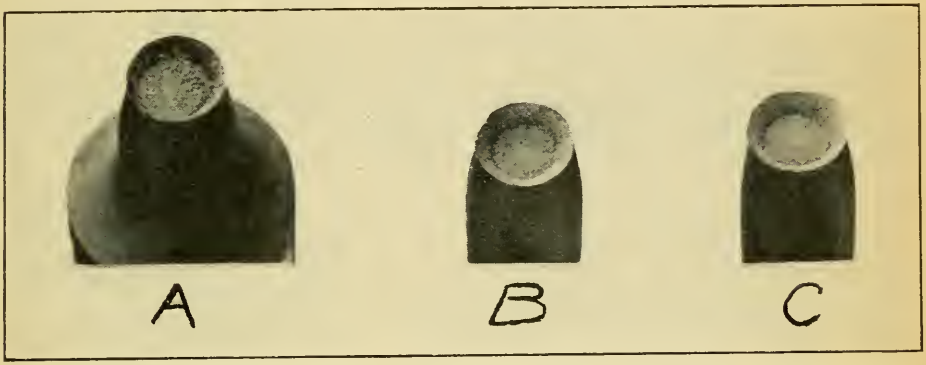

Fig. 13—Photograph showing typical test specimens of high elastic limit steels. *A* is 389 composition, tempered in oil at 1550 degrees Fahr. and drawn at 600 degrees Fahr. *B* is 534 composition, tempered in oil at 1600 degrees Fahr. and drawn at 650 degrees Fahr. *C* is 535 composition, tempered in oil at 1650 degrees Fahr. and drawn at 650 degrees Fahr.

1650 degrees Fahr. for 535. Forging temperatures 1850 to 1950 degrees Fahr.

Microstructures of heat treated cross sections are shown in Figs. 1-13.

The entire non-high-speed series herein described show much improvement over the older high grade silicon-nickel composition 254, and are most promising by reason of the tensile values given in the tables, and by reason of the uniform, tough and dense microstructure of the heat-treated condition.

The physical properties of all these compositions promise much for such purposes as high grade punches, cold sets, chisels, heading dies, rivet sets, automobile axles and springs.

Discussion of Mr. Johnson's Paper

MR. D'ARCAMBAL: About what does the carbon run in those?

MR. JOHNSON: The range is from 0.39 to 0.66 per cent carbon. We found when this steel is treated as described in the foregoing, that the carbon did not have as much influence on the tensile properties as might be expected. We tried one silico-nickel combination in which the carbon was 0.46 per cent. After treating it, we obtained nearly as high figures as we did with 0.66 per cent carbon steel. The alloys seemed to overshadow the carbon content when the steel was treated with a view to getting the highest elastic limit.

MR. D'ARCAMBAL: In looking at some of those figures, the figures resemble those you can get on some of the tougher gear steels.

MR. JOHNSON: Steel of this type might come in under that ap-

plication. You get such good reduction with a 10 per cent elongation that it has possible applications in several lines.

MR. NORTON: Will you kindly explain why you infer that your molybdenum might be a master alloy in that particular composition?

MR. JOHNSON: I did not say that. I said those that were interested in molybdenum might assume that it is a master alloy.

MR. FOLEY: I would like to know why you kept the elongation between 5 and 11. Wouldn't you have been interested in one above that?

MR. JOHNSON: If I got a bigger elongation the tensile properties would be lower. I was after the highest elasticity I could get and still have something measurable in elongation.

MR. SCOTT: What was the etching medium used?

MR. JOHNSON: The ordinary one used, alcohol and nitric acid.

MR. KLINKETT: What was the chemical analysis of the 389 composition?

MR. JOHNSON: It was from 0.40 to 0.60 per cent carbon, in round figures and from 1 to 2 per cent silicon, 0.075 chromium and 0.20 to 0.30 per cent vanadium. Three per cent nickel, of course, entered into it.

PROPERTIES OF SOME STEELS IN THE HARDENING RANGE

By W. R. Chapin

IN THIS paper the term "hardening range" is meant that temperature range within which quenched steel acquires its maximum hardness as tested with the Brinell machine, scleroscope or file. This report applies only to those steels which, when properly quenched, harden throughout the mass, or as it may be expressed, harden "solid" and are martensitic when so hardened.

It is not claimed that this maximum hardness is the greatest hardness possible to obtain in these steels for it is well known that an even greater hardness is made possible by the use of certain quenching mediums and certain high temperatures. The maximum hardness referred to is the greatest hardness obtainable by the employment of commonly used quenching oil or plain water, the quenching temperatures being such as are used in good common practice.

By reference to test No. 1 it will be noted that this specimen which was ½-inch square was 192 Brinell in the annealed condition. The specimen was quenched in oil from a temperature of 1475 degrees Fahr. and taken from the oil in the hardening range.

It will be appreciated readily that the temperature of the piece when taken from the oil is difficult to measure accurately, particularly near the surface. It may be stated, however, from a great many tests removed from the bath in the hardening range and quickly polished for Brinell testing that the color appearing on the polished surface would indicate strongly that this temperature lies between 400 and 500 degrees Fahr.

It is respectfully suggested to those who have sufficiently delicate apparatus and the inclination that this hardening range temperature may be accurately plotted pyrometrically. This may be done by placing a sensitive couple in the center of a piece, protecting the couple by means of a copper tube brazed into the piece and attaching the couple to a sensitive instrument which will record rapid temperature changes.

Specimen No. 1, it will be noted, was 192 Brinell in the hardening range, practically file hard and could be readily deformed. It shrank 0.009-inch in the hardening range and in cooling in the hardening range naturally in the air to the cold, by which is meant room temperature, it expanded 0.011-inch and was 652 Brinell when cold. It will be noted that it expanded only 0.002-inch from the annealed to the cold state. No. 1 is a well known oil hardening, so called "nonshrinking" steel, but as a matter of fact the steel did shrink 0.009-inch in the hardening range and then expanded 0.011-inch in that range.

It is to be noted particularly that specimen No. 1 was entirely unaffected by a powerful horseshoe magnet in the hardening range. This fact was first observed by the writer's assistant W. L. Appel. It is to be noted that this loss of magnetism in the hardening range is most noticeable immediately after withdrawing from the quenching bath and further that there is a gradual return of the magnetic property as the steel cools through the hardening range to the cold. It is also interesting to note that with the gradual return of the magnetic property the Brinell hardness also gradually rises.

The appearance of the Brinell indentation in the hardening range is

A paper presented before the Cleveland Chapter. The author, W. R. Chapin, is director of the testing department, E. C. Atkins & Co., Indianapolis, and president, Deeds & Chapin, Indianapolis.

peculiar in that it is not clear cut but there is a rounding off entirely around the periphery. This appearance is characteristic of all the steels tested in the hardening range.

Referring to test No. 3 it will be seen that this specimen also shrank in the hardening range and showed even a lower Brinell than in the annealed state. No. 3 was also nonmagnetic in that range, could be readily deformed and was practically file hard. It also expanded from the hardening range to the cold and was 652 Brinell when cold. This specimen was a round disk 0.156-inch thick.

In order to determine the Brinell hardness of tests Nos. 1 and 3 in the center of the bar, other samples from the same bars were quenched and brought out in the hardening range, broken and Brinell tested in the center. These pieces were 192 Brinell in the center, practically file hard in the center and were 652 when cold. This test was made repeatedly with the same result each time. Attention is called to test No. 2, which is a well known water hardening steel. The sample was ½-inch square. It will be noted that No. 2

Chemical Analyses of Test Specimens

Test No.	Carbon per cent	M'g'ese per cent	Silicon per cent	Sulphur per cent	Ph'phorus per cent	Chrom'm per cent	Vanad'm per cent	Nickel per cent
1.....	0.770	1.48	0.407	0.021	0.006	0.06	0.19	...
2.....	1.070	0.28	0.404	0.022	0.010	...	...	...
3.....	0.800	0.35	0.200	0.020	0.020	0.40	...	1.25
4.....	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
5.....	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
6.....	1.070	0.28	0.404	0.022	0.010	...	...	...
7.....	1.070	0.28	0.404	0.022	0.010	...	...	...
8	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
9.....	0.890	0.43	0.162	0.018	0.025	0.78	...	1.56
10.....	1.070	0.28	0.404	0.022	0.010	...	...	...
11.....	1.070	0.28	0.404	0.022	0.010	...	...	...
12.....	0.780	0.39	0.146	0.014	0.023	0.32	...	1.36
13.....	1.044	0.48	0.118	0.034	0.010	0.50	...	1.37
14.....	1.112	0.29	0.192	0.023	0.016	...	...	...

expanded continually in the hardening range until cold and was plainly magnetic in that range.

Referring now to test No. 14 it will be seen that this also is an ordinary water hardening tool steel. This steel when quenched in water, as in common practice, is magnetic in the hardening range and expands continually until cold. A specimen cut from bar No. 14 failed to harden in oil in the original size which was ¾-inch wide by 3/16-inch thick but hardened very readily in water.

When bar No. 14 was machined down to 0.050-inch thick, it will be seen that it hardened in oil readily and exhibited all the characteristics of a true oil hardening steel, that is, in the hardening range it first shrank, then expanded, showed a low Brinell gradually increasing and was nonmagnetic. On the other hand, a piece from bar No. 1 when quenched in water and brought out in the hardening range was distinctly magnetic, was file hard, showed a low Brinell and acquired maximum Brinell when cold.

Tests Nos. 12 and 13 are average specimens from 100 tests. They are very interesting in that they show that in the hardening range these steels shrank in every dimension and then expanded in every dimension as they approached the cold. Furthermore these steels shrank upon drawing. No. 12

in the hardening range first shrank 0.195-inch in length and 0.010-inch in width and then expanded 0.232-inch in length and 0.012-inch in width and upon drawing to 800 degrees Fahr., No. 12 shrank 0.236-inch in length and 0.006-inch in width. No. 13 in the hardening range shrank 0.193-inch in length and 0.013-inch in width and then expanded 0.219-inch in length and 0.017-inch in width. In drawing to 800 degrees Fahr., No. 13 shrank 0.128-inch in length and 0.004-inch in width.

No. 12 was 0.100-inch thick and No. 13 was 0.090-inch thick. The change of thickness in the hardening range is not reported on account of the difficulty in getting an accurate measurement on account of rolling scale coming off and on account of getting an accurate record of such a small change as would take place in the thickness. But since these 100 pieces shrank in two dimensions and then expanded in two dimensions it is perfectly logical to expect that they also contracted and then expanded in the third dimension. The 100 specimens were nonmagnetic in the hardening range.

Another specimen from No. 12 and No. 13 was given the same treatment and after being drawn to 800 degrees Fahr. was annealed to produce a pearlitic structure. The measurements were then found to be practically the same as originally. By reference to tests Nos. 4 to 11 inclusive, it will be seen that the rate of cooling from the hardening range to the cold does not affect the ultimate hardness when cold.

A piece from bar No. 1 was quenched in oil and was allowed to cool from the hardening range to the cold in a patented compound requiring an hour to cool. Specimen No. 1 was 192 Brinell in the hardening range and 652 Brinell when cold. It is apparently true moreover that there is less distortion and less ultimate change of volume if these steels are allowed to cool slowly from the hardening range to the cold than when allowed to cool in the quenching bath as in common practice.

It is to be noted that specimen No. 4 was quenched in oil until cold and then drawn at 400 degrees Fahr. in oil for 15 minutes. After drawing it was allowed to cool in the air and was 652 Brinell both before drawing and after drawing. After drawing it could be filed slightly. No. 4 was then drawn again for 15 minutes at 400 degrees Fahr. in oil and after drawing when cold was 627 Brinell and could be filed easily.

No. 5 was quenched in oil from 1500 degrees Fahr. the same as No. 4 but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes. It will be seen that No. 5 was 192 Brinell in the hardening range and was nonmagnetic. After drawing 15 minutes it was 652 Brinell and could be filed slightly. No. 5 was then drawn 15 minutes more at 400 degrees Fahr. in oil and after drawing was 627 Brinell and could be filed easily.

By referring to No. 6 it will be noted that it Brinell tested 179 in the annealed state and upon quenching in water from 1440 degrees Fahr. until cold it expanded 0.013-inch in length and was 683 Brinell when cold. No. 6 after drawing 15 minutes in oil at 400 degrees Fahr. contracted 0.004-inch in length and was 627 Brinell.

It will be seen that No. 7 quenched the same as No. 6 but taken out in the hardening range was 302 Brinell in that range, was magnetic and was practically file hard. No. 7 upon drawing 15 minutes in oil at 400 degrees Fahr. was 627 Brinell and could be filed readily. It will be noted that No. 7, which was cut from the same bar as No. 6, expanded 0.005-inch from the annealed to the cold state whereas No. 6 quenched regularly expanded 0.009-inch from the annealed to the cold.

Referring to test No. 8 it will be seen that after quenching regularly in oil from 1500 degrees Fahr. and then drawn in oil for 15 minutes at 350 degrees Fahr., a piece was 652 Brinell before and after drawing and after drawing was file hard. No. 9 quenched the same way as No. 8 except taken out in the hardening range and drawn at once in oil for 15 minutes at 350 degrees Fahr., was 192 Brinell in the hardening range and was nonmagnetic. After drawing No. 9 was 652 Brinell and file hard.

No. 10 when hardened regularly in water from a temperature of 1440 degrees Fahr. and then drawn at 250 degrees Fahr in oil for 15 minutes was 683 Brinell before and after drawing and was file hard after drawing. No. 11 quenched the same as No. 10 except taken out in the hardening range and drawn at once to 250 degrees Fahr. in oil for 15 minutes was 321 Brinell in the hardening range and was magnetic. After drawing No. 11 was 683 Brinell and file hard.

Results of Hardening Range Tests

Test No. 1. Specimen ½-inch square. Quenched in oil from 1475 degrees Fahr. Removed from bath while in the hardening range.

Test No. 2. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr. Removed from bath while in the hardening range.

Test No. 3. Specimen circular, 0.156-inch gage. Quenched in oil from 1500 degrees Fahr. Removed from bath while in the hardening range.

	Annealed		Hardening Range		Cold	
Test No.	Length inches	Brinell hardness	Length inches	Brinell hardness	Length inches	Brinell hardness
1	4.438	192	4.429	192	4.440	652
2	3.968	179	3.973	262	3.978	652
3	4.993	231	4.980	192	4.996	652

Test No. 4. Specimen quenched in oil from 1500 degrees Fahr. until cold, and then drawn at 400 degrees Fahr. in oil for 15 minutes.

Test No. 5. Specimen quenched in oil from 1500 degrees Fahr., but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes.

	Test No. 4	Test No. 5
Brinell hardness after quenching	652	192 (nonmagnetic)
Brinell hardness after drawing	652	652
Filed	Slightly	Slightly
Brinell hardness after redrawing at 400 degrees Fahr. for 15 minutes	627	627
Filed	Easily	Easily

Test No. 6. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr. until cold, and then drawn at 400 degrees Fahr. in oil for 15 minutes.

Test No. 7. Specimen ½-inch square. Quenched in water from 1440 degrees Fahr., but taken out in the hardening range and drawn at once at 400 degrees Fahr. in oil for 15 minutes.

	Annealed		Quenched		Drawn	
Test No.	Length inches	Brinell hardness	Length inches	Brinell hardness	Length inches	Brinell hardness
6	4.146	179	4.159	683	4.155	627
7	4.171	179	....	302	4.176	627

Test No. 8. Specimen quenches in oil from 1500 degrees Fahr. until cold, and then drawn at 350 degrees Fahr. in oil for 15 minutes.

Test No. 9. Specimen quenched in oil from 1500 degrees Fahr. but taken out in the hardening range and drawn at once at 350 degrees Fahr. in oil for 15 minutes.

	Test No. 8	Test No. 9
Brinell hardness after quenching	652	192 (nonmagnetic)
Brinell hardness after drawing	652	652
Filed	Hard	Hard

Test No. 10. Specimen quenched in water from 1440 degrees Fahr. until cold, and then drawn at 250 degrees Fahr. in oil for 15 minutes.

Test No. 11. Specimen quenched in water from 1440 degrees Fahr. but taken out in the hardening range and drawn at once at 250 degrees Fahr. in oil for 15 minutes.

	Test No. 10	Test No. 11
Brinell hardness after quenching	683	321 (nonmagnetic)
Brinell hardness after drawing	683	683
Filed	Hard	Hard

Test No. 12. Specimen quenched in oil from 1500 degrees Fahr. but taken out in the hardening range. Afterwards drawn at 800 degrees Fahr.

Test No. 13. Specimen in oil from 1500 degrees Fahr., but taken out in the hardening range. Afterwards drawn at 800 degrees Fahr.

	Test No. 12		Test No. 13	
	Length inches	Width inches	Length inches	Width inches
Annealed	60,286	4,694	60,396	6,000
Hardening range	60,091	4,684	60,203	5,987
Cold	60,323	4,696	60,422	6,004
Drawn	60,087	4,690	60,294	6,000

Test No. 14. This specimen, 5.540 x 0.75 x 0.050 inches, was quenched from 1500 degrees Fahr in oil. It was removed from the oil while in the hardening range and proved to be nonmagnetic. Its changes in size, as shown in the following, are in the same proportion as a so-called oil-hardening steel.

	Length inches
Annealed	5.5400
Hardening range	5.5315
Cold	5.5465

By comparing Nos. 6 and 7 and Nos. 10 and 11 it will be seen readily that a drawing temperature of 400 degrees Fahr. was too high for this particular steel for the reason that the martensite was decomposed at this temperature and consequently the piece could be filed readily, whereas Nos. 10 and 11, which were drawn at 250 degrees Fahr., were file hard after drawing.

Comparing Nos. 4 and 5 and Nos. 8 and 9 it is seen that 400 degrees Fahr. is too high for the drawing of this steel for the same reason that applies to Nos. 6 and 7, whereas 350 degrees Fahr. leaves the pieces file hard after drawing.

It seems almost paradoxical that these steels exhibit in the hardening range a low Brinell and at the same time are practically file hard and can be deformed readily. Similar observations have been made on a variety of other steels which harden solid in oil, such steels containing about 1.00 per cent tungsten; chrome and tungsten; chrome, vanadium and tungsten; chrome; and chrome and vanadium. Data is being prepared on high speed steel.

The foregoing tests indicate that all steels, and perhaps high speed steel, when quenched and hardened solid first shrink and then expand. The nonmagnetic properties of water hardening steels in the hardening range are difficult to determine because of the rapidity of quenching but by reference to test No. 14, it is noted that when a water hardening steel hardens solid in oil, it exhibits the characteristic hardening range properties of a regular oil hardened steel and vice versa. It can be shown that an oil hardening steel

like Nos. 1 or 3 when quenched in water have the characteristic properties of a water hardening steel. Therefore, it is logical to assume, and it may even be demonstrated that all steels whether oil or water hardening, which harden solid when quenched, are at some stage of the hardening range nonmagnetic.

Since the steels in this paper, of the oil hardening type and also No. 14, are nonmagnetic in the hardening range, and since it is the theory held by many that all steels above the Ac range contain gamma iron, and since it is well known that steels above the Ac range are nonmagnetic, it naturally follows that the steels in this report contain gamma iron in the hardening range and are therefore austenitic in that range.

Since in order to harden, a steel must pass through the Ar range, it follows that these steels have not passed through the Ar range when taken from the oil in the hardening range but the Ar has been suppressed to a temperature approximating 400 to 500 degrees Fahr. A further deduction is that in the hardening range austenite occupies a smaller volume and has a higher specific gravity than martensite.

This deduction as to the specific gravity of the microconsituents is based entirely on the observations of the change of volume of the steels as noted in these tests and is therefore only a tentative deduction. It may well be proved that these changes of volume are not alone due to the formation of the different microconstituents but also may be due to intermolecular change on account of change of temperature. The writer does not seek to propound theories in this paper but merely wishes to draw attention to certain observations. It is earnestly hoped that these observations may draw from other metallurgists more and clearer reports and deductions.

It would seem safe to say that the practical value of this investigation is that it indicates certain possibilities. It is perfectly apparent from the tests that when a steel which hardens solid is quenched it first contracts and then expands in the hardening range. Since this expansion begins and is most rapid at the thinnest section and in the region farthest from the center of the steel it naturally follows that any quenched steel such as punches, dies, cutters, etc., should be withdrawn from the quenching medium in the hardening range and placed at once in a medium sufficiently hot to permit the martensite to form slowly and completely and uniformly but not hot enough to start the decomposition of the martensite into troostite or sorbite.

It may be stated as a truth that a steel properly treated in the hardening range, providing of course that the steel is of the correct analysis and has been made right, will be less liable to rupture and will show a minimum of deformation.

Attention is called to photomicrographs, Figs. 1, 2, 3 and 4. Fig. 1 is No. 1 steel quenched in oil from 1475 degrees Fahr. until cold and then drawn 15 minutes in oil at 350 degrees Fahr. Fig. 2 is No. 1 steel quenched in oil from 1475 degrees Fahr., removed in the hardening range and drawn at once for 15 minutes in oil at 350 degrees Fahr. Fig. 3. is No. 2 steel quenched in water from 1440 degrees Fahr. until cold and then drawn in oil at 250 degrees Fahr. for 15 minutes. Fig. 4 is No. 2 steel quenched in water from 1440 degrees Fahr., removed in the hardening range and drawn at once in oil at 250 degrees Fahr. for 15 minutes.

Both Figs. 2 and 4 show a much more perfect martensitic structure than Figs. 1 and 3. It would be expected that Figs. 2 and 4 would be much tougher steels than Figs. 1 and 3 and with better cutting qualities. It seems

reasonable to suppose that a steel cooled slowly through the hardening range would be more completely martensitic whereas the same steel quenched regularly might have in its structure some trapped austenite.

It can be stated further that soft spots in oil hardening steels which harden solid can be detected in the hardening range with absolute certainty by

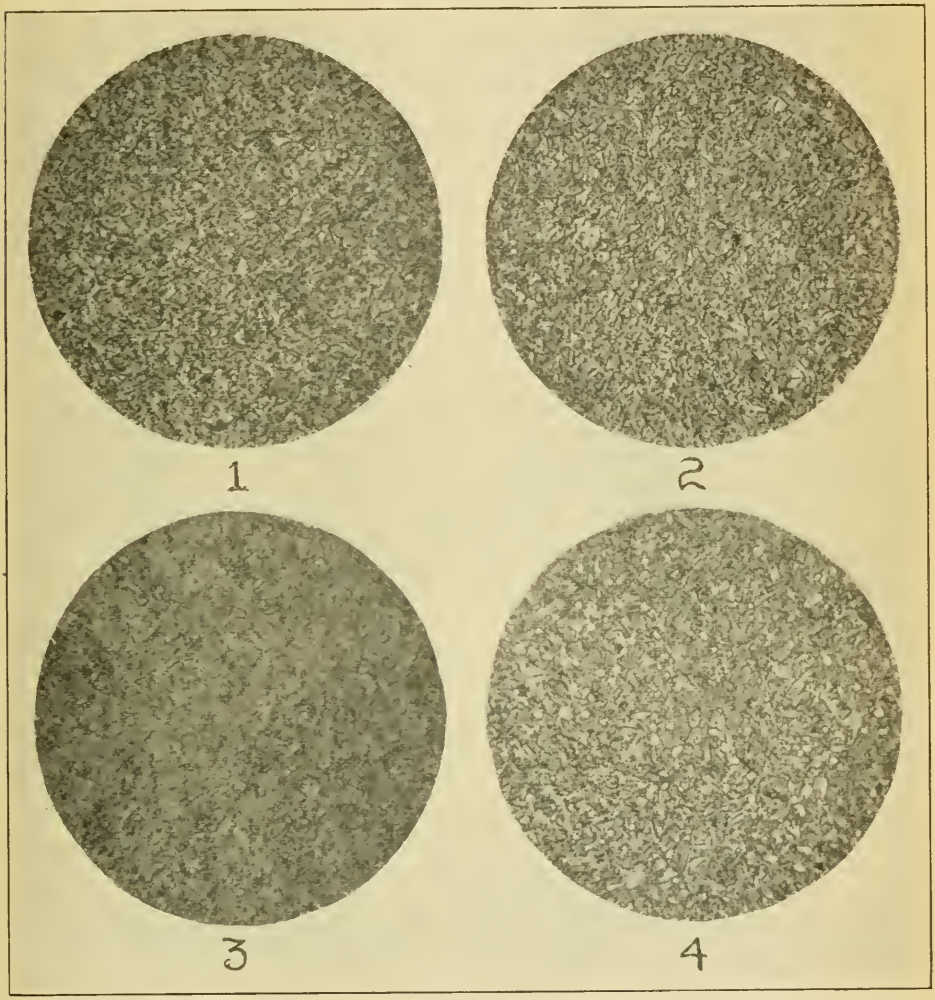

Fig. 1—No. 1 steel quenched in oil from 1475 degrees Fahr. until cold and then drawn 15 minutes in oil at 350 degrees Fahr. X 855. Fig. 2—No 1 steel quenched in oil from 1475 degrees Fahr., removed in the hardening range and drawn at once for 15 minutes in oil at 350 degrees Fahr. X 855. Fig. 3—No. 2 steel quenched in water from 1440 degrees Fahr. until cold and then drawn in oil at 250 degrees Fahr. for 15 minutes. X 855. Fig. 4—No. 2 steel quenched in water from 1440 degrees Fahr., removed in the hardening range and drawn at once in oil at 250 degrees Fahr. for 15 minutes. X 855

the use of a magnet. The writer has demonstrated this beyond a reasonable doubt. It should be strongly emphasized that a steel taken from the quenching bath in the hardening range should be placed at once in a medium of the proper temperature. Steels withdrawn in the hardening range are very liable to rupture if allowed to cool in the air. The reason is perfectly obvious.

Indeed, it seems almost a miracle that all quenched steels do not fly to

pieces and it can only be explained, at least to the writer's mind, by the fact that the Great Creator Himself gave the hardening power of steel for the use of mankind.

The author desires to give acknowledgement and thanks to W. L. Appel, assistant director of testing department, for his able and enthusiastic co-operation in the preparation of this paper.

DISCUSSION OF MR. CHAPIN'S PAPER

By Zay Jeffries

THIS work of Mr. Chapin fills an important gap in the history of steel treating. In the early days of the study of critical points and study of structure under the microscope, it was believed that the rapid cooling of steel from above its critical point did not greatly change the temperature of transformation but it was known that the resulting structures and physical properties were greatly changed by the rapid cooling through the critical range. A few years ago Portevin and Garvin[1] showed by thermal analysis that the constituent known as martensite, which is the hard constituent in steel produced by quenching, was in reality formed at a temperature near 300 degrees Cent., whereas the transformation on slow cooling takes place at a temperature near 700 degrees Cent.

Mr. Chapin now confirms the conclusions of Portevin and Garvin and adds the very important information that the rate of transformation of austenite to martensite is sufficiently slow within the temperature ranges of 200 to 300 degrees Cent. approximately, that Brinell hardness measurements and length measurements can be made on the steel while it is still austenite, after which martensite forms quickly with further cooling or more leisurely if the steel is allowed to remain at a temperature of 200-300 degrees Cent.

Mr. Chapin's results also make it possible to calculate more accurately the increase in volume when austenite changes to martensite than has heretofore been possible. Taking his tests Nos. 1, 2, 3, 12, 13, and 14, it is found that there is an average increase in length of 0.31 per cent of the martensite at room temperature as compared to austenite at a temperature which we will call about 200 degrees Cent. Inasmuch as the steel should contract about 0.25 per cent on cooling from about 200 degrees Cent. to room temperature, it is probable that the actual increase in length at the temperature where martensite is formed is about 0.55 per cent. This would mean an increase in volume of about 1.65 per cent. There seems to be no particular relation between the increase in length and the increase in hardness inasmuch as sample No. 1 which increased 0.24 per cent in length was as hard as sample No. 13, which increased 0.37 per cent in length.

Dr. Arne Westgren in Sweden and Mr. Bain and the writer in Cleveland, have shown definitely by means of X-ray crystal analysis that the crystal lattice of austenite is face centered cubic and that of ferrite, that is ordinary alpha iron, is body centered cubic. We have also shown that manganese steel which is also austenitic has a face centered cubic lattice whereas martensite has the same lattices as alpha iron. For the first time, therefore, we are sure that martensite is alpha iron, or at least that

1—Journal, Iron and Steel Institute, No. 1, 1919, p. 469.

The author, Zay Jeffries, is director of research, Aluminum Co. of America, Cleveland.

alpha iron is the principal constituent of martensite. This is consistent with the fact that the change of austenite to martensite is always accompanied by an increase in volume because the face centered cubic lattice of austenite represents close packing of the atoms, whereas the body centered lattice of ferrite is not a close packed lattice.

In *Chemical and Metallurgical Engineering* for June 15, 1921, R. S. Archer and the writer presented a paper entitled "The Slip Interference Theory of the Hardening of Metals" in which we put forth the proposition that martensite is composed of very fine grains of ferrite and is hard chiefly because of the fineness of the grain. The expansion when austenite changes to martensite is typical of the expansion which takes place when pure gamma iron changes to alpha iron. In steels we consider that the carbon is dissolved in the austenite as individual atoms of carbon. Ferrite does not dissolve any considerable quantity of carbon. Therefore, when austenite changes normally to its transformation constituents, the iron changes to the alpha form and the atoms of carbon combine with the proper proportion of iron to form the compound Fe_3C. The formation of this compound is accompanied by a contraction and in a steel containing about 1 per cent carbon, the contraction due to the formation of cementite is about equal to the expansion due to the change of gamma iron to alpha iron, so that slowly cooled steels of this composition show no appreciable volume change at the critical temperature.

When steels of this composition are quenched, however, as shown more accurately in Mr. Chapin's paper than heretofore, the expansion takes place just as if the carbide had not formed simultaneously with the formation of martensite. Other considerations point to the same conclusion. If the carbide is allowed to form, contraction immediately sets in. Also the heat given off when a 1 per cent carbon steel changes from austenite to pearlite at a temperature of about 700 degrees Cent. is partly due to the transformation of gamma iron to alpha iron and partly to the formation of cementite. There is heat given off when austenite changes to martensite but it is not so much as when austenite changes to pearlite. When martensite is heated gently a further heat evolution goes on within the metal which presumably is the heat generated by the carbide formation. Another observation by Honda also points to the conclusion that the carbide has not formed in freshly formed martensite. Cementite itself has a magnetic transformation point at about 220 degrees Cent. This point is not observed on heating freshly formed martensite but after the martensite has been heated to 300 degrees Cent., the point is observed either on cooling or heating.

These and other considerations lead to the conclusions which Mr Archer and the writer came to in the paper above cited. The work reported by Mr. Chapin is in complete harmony with these ideas and in addition it gives us a better picture of the actual formation of martensite than has ever before been presented.

GHOST LINES AND GRAIN ELONGATIONS IN HOT ROLLED AND COLD DRAWN LOW CARBON STEEL WIRE

By N. B. Hoffman

TO SHOW the relation existing between ghost lines, bands, and elongated grain structures, as found in low carbon steel wire, is the purpose of this article. In considering a subject of this kind, we should first decide just what is a ghost line, a band, an elongated grain structure, and what metallurgical conditions lend themselves to their production and growth. Some metallurgists are prone to call all three of them ghost lines, while others would call them bands.

Technically speaking, it is generally interpreted that a ghost line in the metal, when under examination with the microscope, contains white bands or streaks of ferrite of various widths and lengths which are impregnated with abnormally large proportions of manganese sulphide and phosphorus. They may be brought about by several causes. Rosenhain says phosphorus is present in solid solution in the ferrite of the ingot, but in the form of solid solution cores, so that the phosphorus content of each crystal increases from its center to its periphery. When rolled out these crystal cores assume the form of elongated masses, and although the ferrite itself undergoes complete recrystallization possibly repeatedly, there is nothing to cause the phosphorus to migrate except the process of diffusion, which is particularly slow in that case. The result is that in the finished material the phosphorus rich ferrite still remains in long bands or streaks and these bands pass indifferently through numbers of individual crystals, indeed, an individual crystal may be partly within and partly outside of the bands. The growing ferrite crystal has simply used the material it found at hand whether rich in phosphorus or not.

Another claim is that ghost lines are formed in rolling or forging through the crystallizing of ferrite around strings of enclosures which are elongated in the direction of rolling. Particularly is this condition found in rolling at high temperatures. All steel contains a certain amount of sonims, or solid nonmetallic impurities, and when these amounts are small, finely divided and uniformly distributed throughout the metal, they should not be detrimental to the efficiency of the steel, but when the sonims are segregated and elongated as found in ghost lines, they produce points of weakness.

More or less confliction of opinion exists concerning bands. The author finds most authorities use the word band when referring to an elongated line of ferrite, which is simply another way of referring to a ghost line. Elongated grain structures as caused by cold work either in drawing or cold rolling, can be restored by annealing and you do not have the inclusion of nonmetallics. This condition is confined principally to low carbon wire steels having a carbon content under 0.20 per cent.

When a steel wire is reduced in area by drawing through a draw plate, the grain structure is elongated in the direction of drafting with each successive draw until a point is reached where the grains have been elongated to their limit of ductility and break due to brittleness. To overcome this condition the wire is given what is known as a process anneal at various stages during the reduction in area. This annealing process is usually

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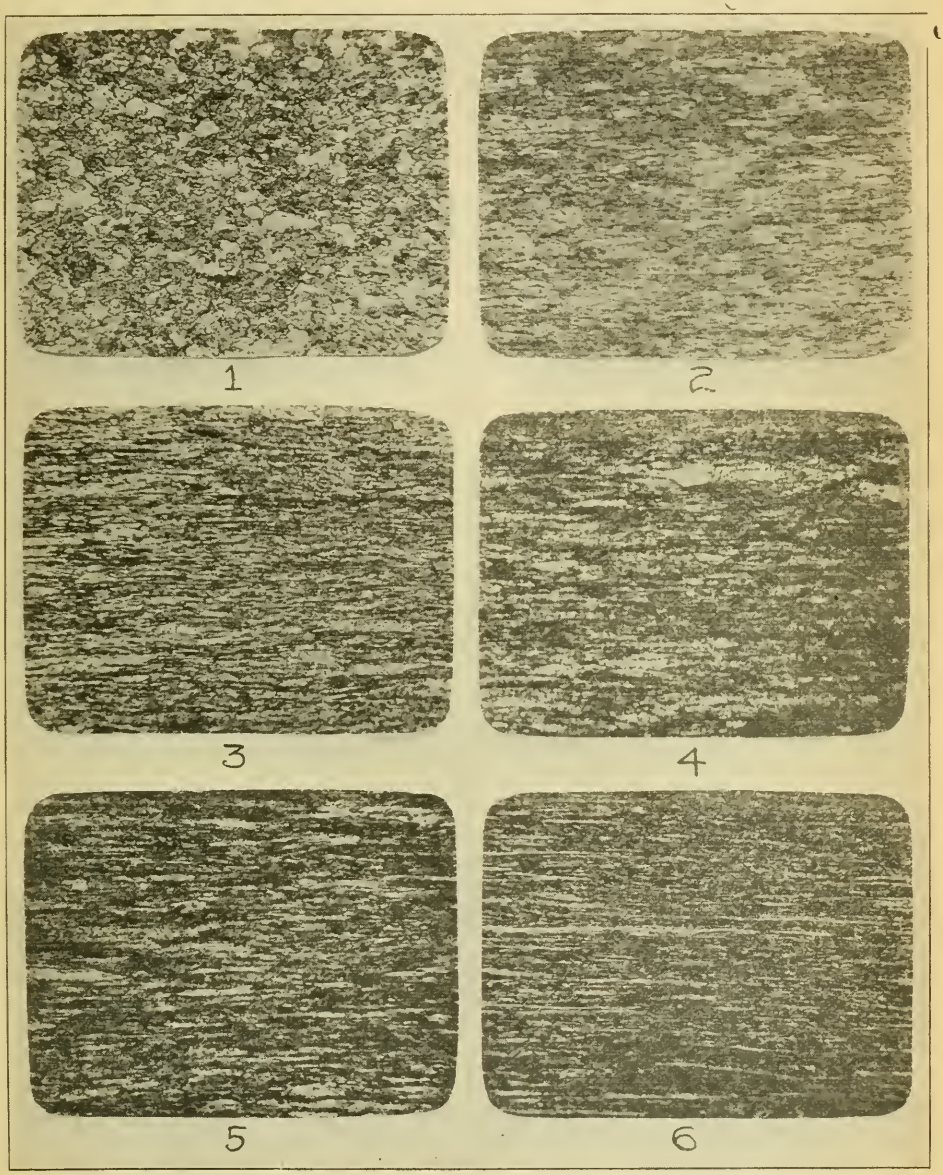
A paper presented at the Indianapolis Convention. The author, N. B. Hoffman, is chemist and metallurgist, Colonial Steel Co., Pittsburgh.

accomplished by heating the wire to between 1200 to 1280 degrees Fahr. and quenching the coil in water at a temperature of 65 degrees Fahr. It might also be said that in the excessive reduction of area without an anneal we invite another hazard, which of course has no direct bearing



Grain structures of hot rolled low carbon open-hearth steel wire during rolling operations. Fig. 1—Grain structure of 0.312-inch diameter steel rod following anneal at 1280 degrees Fahr. X 75. Fig. 2—Same wire after one pass and reduced to 0.251 inches. X 75. Fig. 3—Same wire after two passes and reduced to 0.197 inches. X 75. Fig. 4—Same wire after three passes and reduced to 0.175 inches. X 75. Fig. 5—Same wire after four passes and reduced to 0.148 inches. X 100. Fig. 6—Same wire after six passes and reduced to 0.108 inches. X 75.

on elongated grain structures. That is cupping and by it we mean a cupped shaped fracture in the center of the wire. This condition is caused by the center of the wire being harder than the surface and when it is drawn through the die, the surface flows faster than the center, thereby causing an uneven strain on its internal structure, finally producing the cupped shape internal fracture.

In analyzing the three structures, two types of steel were used, one a high grade basic open hearth and the other a basic bessemer. The analysis of each type is as follows:

Open Hearth	Per cent	Bessemer	Per cent
Carbon	0.19	Carbon	0.13
Manganese	0.21	Manganese	0.43
Phosphorus	0.010	Phosphorus	0.082
Sulphur	0.032	Sulphur	0.047
Silicon	0.09	Silicon	0.11

The basic open-hearth steel was hot rolled to 0.312 inch after which it was cold drawn by the usual process. The bessemer steel was hot rolled to 0.207 inch, after which it was given two draws and reduced in diameter to 0.148 inch.

Ghosts rich in phosphorus may be revealed by several methods. One of the more important is by the use of Stead's copper reagent, which is prepared as follows:

Cupric chloride	10 grams
Magnesium chloride	40 grams
Hydrochloric acid	20 cubic centimeters
Ethyl alcohol to make up to	1000 cubic centimeters

The above salts are dissolved in water to saturation and the whole made up to 1000 cubic centimeters with ethyl alcohol. The specimen is covered with a thin layer of the reagent and is never immersed in a bath of the liquid. The layer of liquid after remaining on the surface for one minute, is shaken off and a second layer dropped on the surface and left for the same period. This procedure is repeated as often as it is found desirable, after which the specimen is washed with boiling water and then with alcohol. The sample is heated enough by the water to remove the last traces of alcohol. If the reagent is applied in successive portions and the difference in the proportion of phosphorus be slight, the copper invariably precipitates on the purer portions first; but on repeated applications the copper gradually deposits also on the parts richer in phosphorus, and after many applications of the reagent the whole surface including the phosphorized parts, becomes coated with copper. However, if the phosphorus is very much concentrated in one or more parts, these remain perfectly bright and free from copper even after 10 applications of the reagent.

In showing micrographs, the author has used the center of the wire and a section longitudinal to the rolling or drawing axis of the same. All etching was done with an alcoholic solution of 5 per cent nitric acid and all micrographs are 75 diameter magnifications unless otherwise noted. We will first consider a basic open-hearth drawn wire showing the gradual breaking up or elongation of the grain structure after each pass.

The wire was hot rolled to 0.312-inch rod after which the coil was heated to 1280 degrees Fahr. and quenched in water at 65 degrees Fahr. This treatment would give a semi or process anneal, and is the method

generally used for this class of work. Fig. 1 shows the grain structure of the 0.312-inch rod after it has received a water anneal at 1280 degrees Fahr. Fig. 2 was taken after the preceding rod had received one pass and reduced in diameter from 0.312 to 0.251 inch. It shows a gradual breaking up of the grain structure. Fig. 3 was taken after the wire had

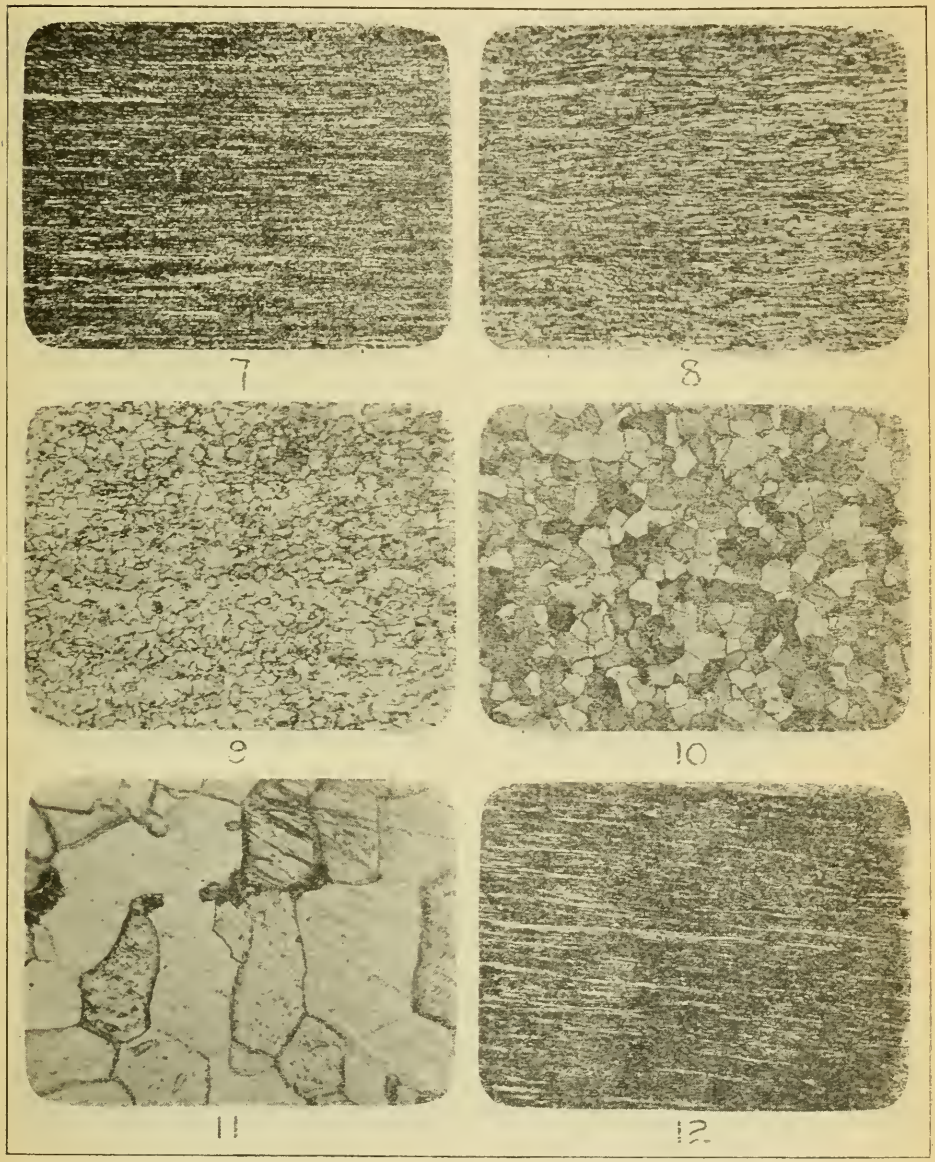


Fig. 7—Same wire as in Fig. 1 after 10 passes and reduced to 0.070 inch. X 75. Fig. 8—Structure of open-hearth steel wire after two draws, being reduced from 0.312 to 0.197 inch. X 75. Fig. 9—A section of the wire drawn to 0.197 inch and heated to 1350 degrees Fahr. X 75. Fig. 10—Same as Fig. 9 but heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 11—Same as Fig. 10 but X 330. Fig. 12—A specimen reduced from 0.312 to 0.108 inch in six draws without heat treatment. X 75.

received two passes, and had been reduced in diameter from 0.251 to 0.197 inch and shows the grain structure beginning to break up and elongate in the direction of drawing.

Fig. 4 was taken after the wire had received three passes, and had been reduced in diameter from 0.197 to 0.175 inch and shows the grain

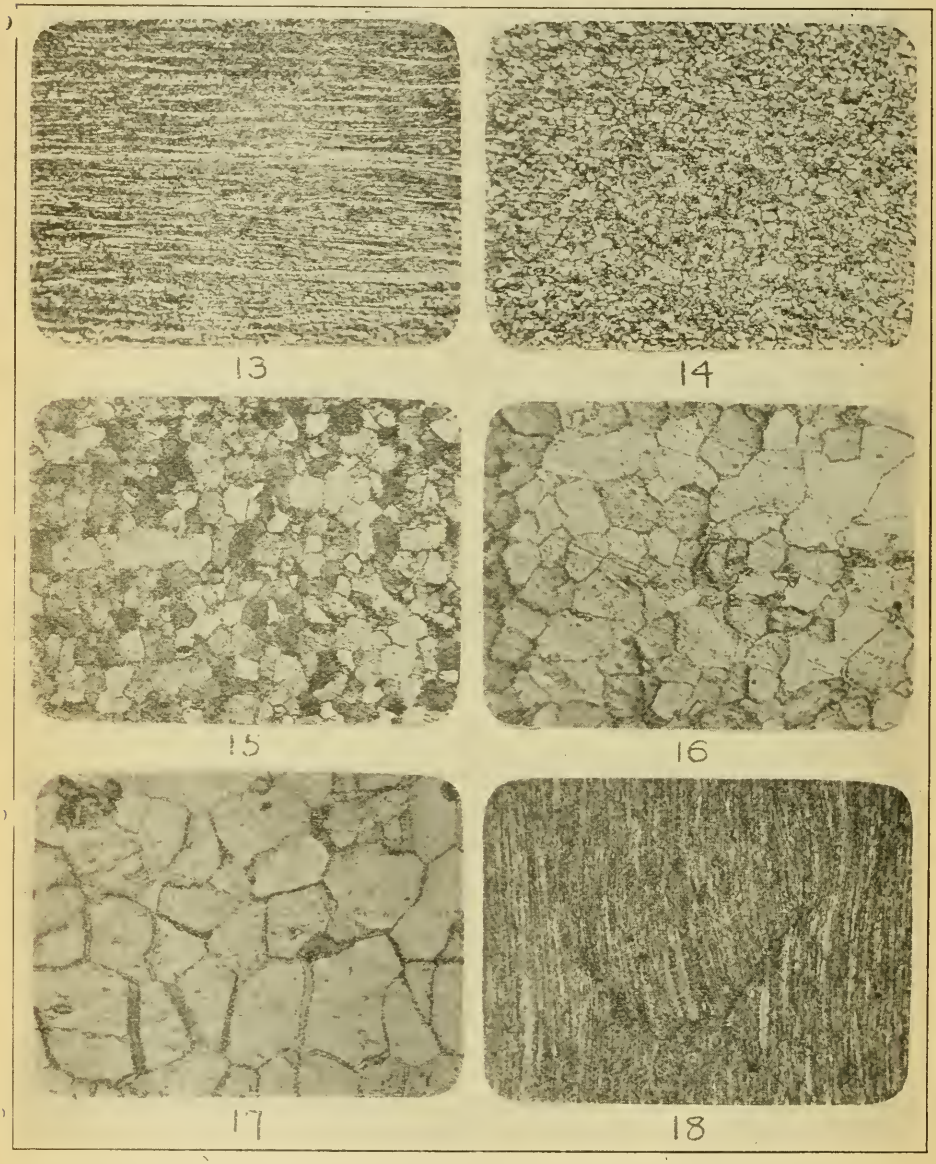


Fig. 13—Same specimen as Fig. 12 but X 150. Fig. 14—Same as Fig. 12 but heated to 1350 degrees Fahr. and cooled slowly. X 75. Fig. 15—Fig. 14 heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 16—Same as Fig. 15 but X 150. Fig. 17—Same as Fig. 15 but X 330. Fig. 18—An overdrawn specimen showing the characteristic cup fracture. X 75.

structure continuing to break up. Fig. 5 was taken after the wire had received four passes, and had been reduced in diameter from 0.175 to 0.148 inch. In this we see the grain structure being still further elongated. Fig. 6 was taken after the wire had received six passes and had been reduced in diameter from 0.148 to 0.108 inch. In this we see the grain structure so badly elongated as to indicate ghosts. Fig. 7 was taken after the wire had received 10 passes and had been reduced in diameter from 0.108 to 0.070 inch. In this micrograph we find the grain structure very badly elongated.

We will next take two of the drawn samples exhibiting the elongated grain structures which are often confused as ghost lines, anneal them and note the restoration of grain structure and the absence of any impregnated nonmetallic inclusions. Fig. 8 is a section of wire which has had two draws, being reduced in diameter from 0.312 to 0.197 inch. Fig. 9 is a section of the wire which has been drawn to 0.197 inch and heated to 1350 degrees Fahr., and even at this low temperature we find the elongated grain structure practically broken up, but of course the heat has not been carried high enough to have any real grain growth. Fig. 10 shows the preceding specimen heated to 1600 degrees Fahr. and cooled slowly. In this we see a good recrystallized grain structure containing no impregnated impurities. Fig. 11 is a view of the preceding specimen which had been heated to 1600 degrees Fahr. and magnified at 330 diameters.

Fig. 12 is a specimen that has been reduced in diameter from 0.312 to 0.108 inch in six draws without any heat treatment. It shows a badly elongated grain structure. Fig. 13 is from the same specimen as the preceding micrograph, but magnified at 150 diameters, and shows plainly what is often called ghost lines. Fig. 14 is the same specimen which has been reduced in diameter from 0.312 to 0.108, and which has been heated to 1350 degrees Fahr. and cooled slowly. In it we again see the elongated grains rearranging themselves to form a new structure. Fig. 15 shows the preceding specimen heated to 1600 degrees Fahr. and cooled slowly. In this we see a good crystallized grain structure containing no impregnated impurities. Fig. 16 is the same specimen as shown in the preceding micrograph magnified at 150 diameters. Fig. 17 is the same specimen as shown in the preceding micrograph magnified at 330 diameters. Fig. 18 is from a specimen of wire which had been overdrawn, and exhibits the characteristic cup fracture.

We will next consider a sample of hot rolled bessemer steel, the micrographs show these samples to contain well defined ghost lines. Fig. 19 shows a section of wire after it was hot rolled to 0.207-inch and drawn to 0.148-inch in two draws without any heat treatment, and shows three distinct bands which after heat treatment are shown to be true ghost lines. Fig. 20 is the same specimen as shown in the preceding micrograph, except that it has been heated to 1350 degrees Fahr. and allowed to cool slowly. In it we see the bands persisting but with the ferrite beginning to recrystallize. Comparing this micrograph with Fig. 14, in the elongated grain structure series shows the persistence of the bands in the latter instance. Fig. 21 is from the same specimen as the preceding micrograph except that it has been heated to 1600 degrees Fahr. and cooled slowly. Fig. 22 is the same specimen as in the preceding micrograph except that it has been heated to 1700 degrees Fahr. and allowed to cool slowly. In it we see the grain structure entirely broken

up, but with the lines of inclusions which are high in phosphorus intact. It is also noted that they extend directly through the grains and do not follow the grain boundaries. Fig. 23 is another view of the preceding specimen, magnified at 150 diameters to show the line of inclusions high in phosphorus running directly through the grains. Fig. 24 is a view of the preceding specimen magnified at 330 diameters, to show the en-

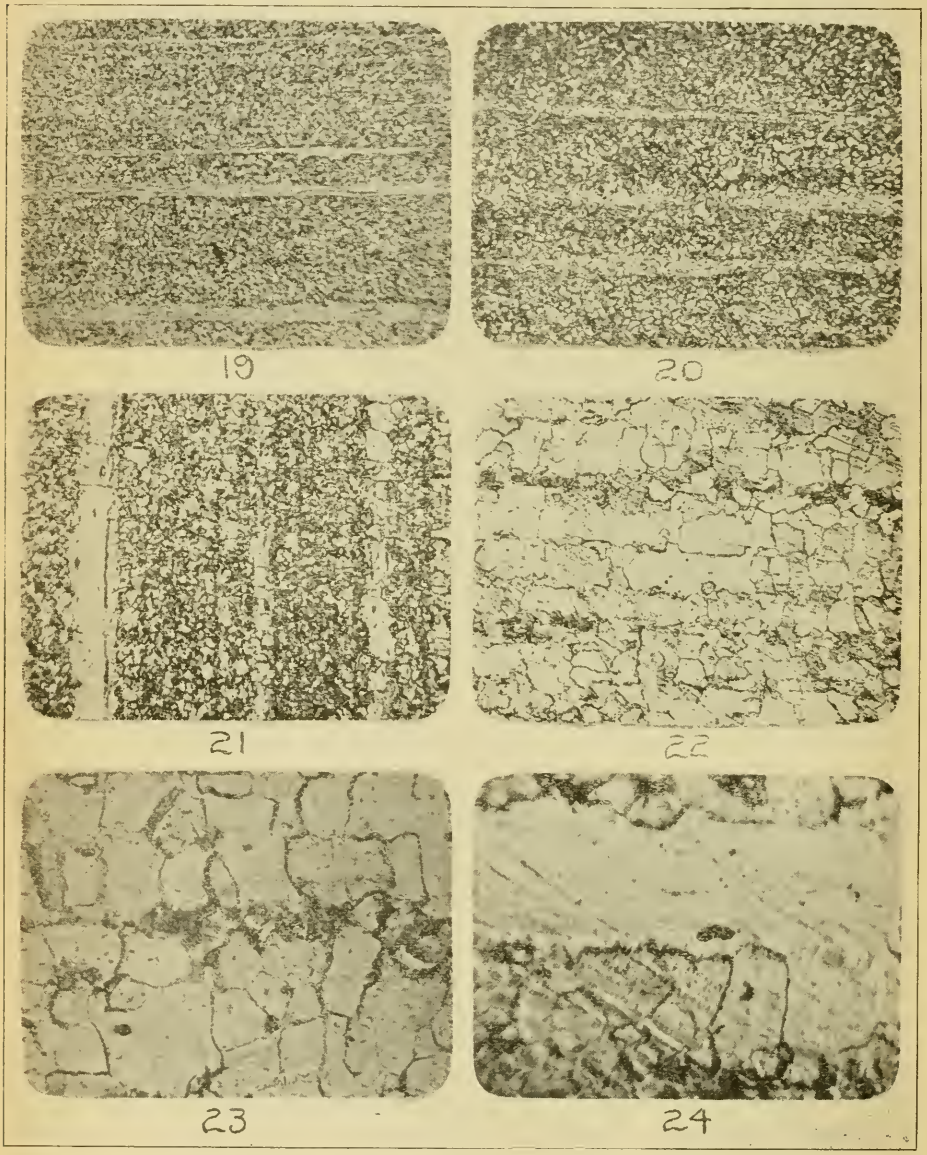
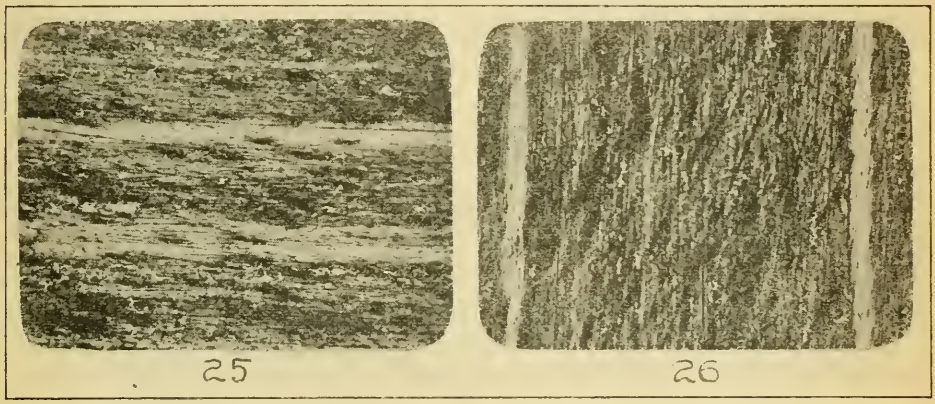


Fig. 19—Structure of a bessemer steel wire hot rolled to 0.207-inch diameter and drawn to 0.148 inches in two draws without heat treatment. X 75. Fig. 20—Same as Fig. 19 but heated to 1350 degrees Fahr. and cooled slowly. X 75. Fig. 21—Same as Fig. 19 but heated to 1600 degrees Fahr. and cooled slowly. X 75. Fig. 22—Same as Fig. 19 but heated to 1700 degrees Fahr. and cooled slowly. X 75. Fig. 23—Same as Fig. 22 but X 150. Fig. 24—Same as Fig. 22 but X 330.

larged grain growth due to the presence of phosphorus in solid solution in the grain. It will be noted that one grain covers practically the entire micrograph.

A specimen of bessemer wire as drawn and shown in Fig. 19, was heated to 1600 degrees Fahr. and cooled slowly, then polished and etched with Steads copper reagent, as previously described. Copper is precipitated on the parts low in phosphorus and not on the areas high in phosphorus, and in the following micrographs, Figs. 25 and 26, which represent the above copper treated specimen, is noted the distinct heavy white lines or ghosts high in phosphorus.

In conclusion the author might say that in examining steels low in phosphorus and sulphur, he has found but few ghost lines, while in



Figs. 25 and 26—Specimen shown in Fig. 19 heated to 1600 degrees Fahr. and cooled slowly, then polished and etched with Stead's copper reagent. X 75. Heavy white lines represent ghosts high in phosphorus.

steels high in sulphur and phosphorus, they have often been very prolific due to the presence of much material necessary for their growth. We all have our pet ideas as to the most fertile conditions for the growth of ghost lines, but personally the author believes there are as many formed by very hot rolling as produced by any other cause. He also believes that hot rolling has as much to do with it as the freezing of dendritic properties in the ingots.

Discussion of Mr. Hoffman's Paper

MEMBER: How many passes were made of that steel wire before you got your first fracture? You say you reduced it from 0.312 to 0.079 inches?

MR. HOFFMAN: You mean, how many passes were made on the wire?

MEMBER: Yes, before it got so brittle it broke in the operation.

MR. HOFFMAN: Ten. I believe you are as familiar with the ordinary practice as I am. If I am not mistaken, five drafts are considered the maximum, although most people do not take over three.

MEMBER: You annealed the open-hearth bar after hot rolling before you started drawing?

MR. HOFFMAN: Yes.

MR. FOLEY: What is the effect of that striation of which you mention on the quality of wire?

MR. HOFFMAN: Brittleness.

MR. FOLEY: Brittle wire with long stringers in it?

MR. HOFFMAN: Absolutely. Where you have an elongated section such as shown in Fig. 23, with a line of sonims running directly through the grain structure, the metal body is naturally weakened.

MR. FOLEY: The bands themselves are the cause of brittleness?

MR. HOFFMAN: The phosphides and sulphides are really the cause of brittleness, naturally, but a wire overdrawn, we will say, is bound to be brittle, but that same wire will get brittle much quicker if it were full of sonims and ghost lines.

MR. FOLEY: You find when you have the long bands or ghosts that it will break quicker than otherwise?

MR. HOFFMAN: Yes and you will be surprised how numerous they are in some wires.

MR. FOLEY: In the case of the bessemer wire, did you just draw the two passes and quit?

MR. HOFFMAN: Yes.

MEMBER: You have no comparison?

MR. HOFFMAN: No comparison. I did not draw it down to the same number of passes for the reason that my only thought was to show the comparison between elongated grain structure and a ghost line.

MR. FOLEY: Wrought iron would be particularly brittle.

MR. HOFFMAN: Wrought iron is permeated with elongated slag inclusions, and as hot rolled it is not brittle, but were it reduced by drawing through a draw plate as in a wire, undoubtedly it would be weak.

MR. SCOTT: The carbon point in both wires was very low?

MR. HOFFMAN: Very low. Ten.

MR. SCOTT: Which structure did you use? You had two or three various grain sizes. You used the smallest?

MR. HOFFMAN: I dont quite get your question. I used the various grain sizes obtained through the different heat treatments.

MR. SCOTT: I wondered what your finished product was.

MR. HOFFMAN: The finished product, we will say, really should be around the third draw, after the third or fourth draw, which was shown.

MR. SCOTT: That was annealed at 1350 degrees Fahr.?

MR. HOFFMAN: You would not have a finished product in any annealed condition.

MR. SCOTT: I did not think so.

MR. HOFFMAN: No, the micrograph in Fig. 5 will illustrate that point. The idea of the process of annealing, of course, is to make the metal malleable in order that it may be worked readily. I wouldn't carry a wire any further than the reduction shown. If you did I would say it would be liable to be dangerous. That has had four draws, rather

heavy ones. When you say so many draws and so many drafts you must assume reduction at the same time.

MR. FOLEY: Why do you say that hot working would be responsible for this rather than that they have their hardness in the dendritic structure? How could hot working cause it?

MR. HOFFMAN: It is claimed in hot working the nonmetallics flow together and the ferrite crystallizes around the sonims, just the same as it would in the ingot. My assertion has been caused more through observation. I have noticed in numerous cases where some wires of the same batch of metal would be hot worked and the others cold worked, the hot worked material invariably would be worse than the cold worked metal.

MR. FOLEY: I know you have used agents in trying to get rid of that same banded structure, used a high temperature for a long time for the purpose of diffusing the phosphite and sulphite. Is it safe to do it at a high temperature?

MR. HOFFMAN: I used a high temperature to crystallize the ferrite.

MR. FOLEY: The high temperature promoted a diffusion?

MR. HOFFMAN: No. Merely recrystallizes the ferrite.

MR. FOLEY: I remember Charpy did the same thing with a high temperature. He succeeded in diffusing phosphite and sulphite and in breaking up the structure.

MR. HOFFMAN: Yes, by soaking at a high heat for a number of days, but that procedure would be impossible as a commercial proposition.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

CARBON CONTENT CORRECTED

IN THE discussion "Cyanide Data Seems Confusing" by Stanley P. Rockwell, which appeared on page 442 of the February TRANSACTIONS, the carbon contents mentioned in the first paragraph were found to be in error. When corrected the second and third lines should read "Various investigations have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.3 to 0.6 per cent."

EFFICIENCY OF DIFFERENT MIXTURES FOR CYANIDE HARDENING AND THE ROLE OF NITROGEN IN THE PROCESS

THE following comments are relevant to the constructive criticisms which appeared on page 443 of the February TRANSACTIONS. With reference to Mr. Brophy's remarks, the author is pleased to reply thereto in the order of their presentation:

Depth of Case. The depth of case, as recorded in the subject paper, "is ascertained by measuring the distance from the outer edge of the specimen to the center of the second zone." Mr. Brophy writes that he measured the depth of penetration by "estimating the distance from the surface to the innermost needle." Such procedure, in my opinion, is uncertain. Nitrogen needles possess a roving tendency. They may be found in cyanided specimens at depths appreciably below the accepted case. The writer's paper purports to the depth of case, whereas Mr. Brophy's criticism deals with the depth of nitrogen penetration. They are distinct.

Carburizing Action. The writer's use of the word carburizing is justified. Attention is also called to the fact that Mr. Brophy uses the word in a similar sense namely: "When Na_2CO_3 is melted it is a well known fact that CO_2 is liberated, also that NaCN is an active reducing agent. Therefore, is it not possible that CO_2 is reduced to CO with the formation of NaOCN, and the steel carburized by CO?" Carburizing is defined as the introduction of carbon into steel or iron while the metal is below the melting temperature. Mr. Brophy's experiments confirm the writer's use of the word carburizing. His original specimen contained no carbon. An analysis subsequent to the cyaniding operation revealed 0.33 per cent carbon.

It is admitted that nitrogen hardens steel, but it is equally true that carbon functions in a similar manner. The hardness of the cyanide case, is in the writer's opinion, the result of the combined influences of nitrogen and carbon.

Sodium Carbonate. Mr. Brophy also questions the accuracy of the statement that sodium carbonate is inert. Attention is directed to the Curve *B*

in the subject paper page 298, January TRANSACTIONS, which represents the performance of a bath containing 76 per cent sodium cyanide, and 22.5 per cent sodium chloride. Note the absence of sodium carbonate. Notwithstanding, carburization has taken place. The curve practically parallels the performance of the bath which contains 54 per cent sodium carbonate. Therefore, by a process of elimination, the writer re-affirms his statement that sodium carbonate is inert.

Flavite. Mr. Brophy further states that "the term 'Flavite' given to this patch constituent by Mr. Hillman, is a new one, not having been used in previous publications." The word was used by J. Kirner in his publication which records his remarkable observations on the case hardening of steel, especially in regard to the effect of nitrogen; "Metallurgie" 1911, Vol. 8, page 72. In the 1915 edition of Giolitti's admirable work on the "Cementation of Iron and Steel," the word appears on page 139 in precisely the same role as that used by the author.

V. E. HILLMAN, Metallurgist,
Crompton & Knowles Loom Works,
Worcester, Mass.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

QUESTION NO. 7. May tools be heat treated properly in a furnace in which copper is present?

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 9. In carbonizing does not the carbon increase slightly even in the core section?

QUESTION NO. 10. What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?

QUESTION NO. 11. Has high speed steel ever been carbonized and if so what were the results?

QUESTION NO. 12. How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

QUESTION NO. 13. A swaging die for tubing receives 3600 blows per minute. It has been found that a scleroscope hardness of about 95 is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?

QUESTION NO. 14. What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.

QUESTION NO. 17. For some time past we have been water quenching steel castings in order to improve their physical properties. These castings are mostly shrouded pinions and plain rollers, weighing from 150 to 500 pounds each. These pieces would be immersed in the water bath for a short period of time, usually from one to two minutes and then withdrawn and

allowed to cool in the air. Our results have been satisfactory but we feel that we can improve this method somewhat by a slight modification in the treatment. In order to relieve cooling strains, one suggestion is that we provide a tank filled with infusorial earth in which the castings would be placed in order that cooling might be slow and uniform. Another suggestion is that instead of using a plain water bath, we introduce sodium hydrate in order that the quenching may not be quite so severe. We would like to know which of the above plans would be the better or if there is any other better plan which could be suggested. We do not care to use oil because of its expense.

NOTE. Rollers may break in the flange a month or more after above treatment. Loss at present is 2 per cent. Pinions, after above treatment, are drawn in furnace to 1200 degrees Fahr. for toughness. If drawn shortly after quenching there is no trouble, but this is not always practicable when working day turn only. If allowed to stand in air after quenching, cracking may result, hence the suggestion for covering with infusorial earth or ashes. We have had only one batch to show cracks.

QUESTION NO. 18. *What is the relationship between Brinell and Scleroscope hardness?*

ANSWER. By C. F. Green, Henry Souther Engineering Co., Hartford, Conn. Robert R. Abbott has determined the relation between Brinell and scleroscope hardness probably as definitely as it is possible to do so in his contribution to the *Proceedings* of the American Society for Testing Materials, 1915, Vol. XV, under the title "The Relation Between Maximum Strength, Brinell Hardness and Scleroscope Hardness in Treated and Untreated Alloy and Plain Steels." His tests show that the relationship varies in different grades of steel, and a table of equations for converting from one scale to the other is given for the more common kinds:

Kind of Steel	Equation
Carbon steel	Brinell equals 5.6 scleroscope plus 14
Nickel steel	Brinell equals 5.0 scleroscope plus 48
Chrome-vanadium steel	Brinell equals 5.5 scleroscope plus 27
Low chrome-nickel steel	Brinell equals 5.4 scleroscope plus 33
High chrome-nickel steel	Brinell equals 4.8 scleroscope plus 58
All steels grouped together	Brinell equals 5.5 scleroscope plus 28

QUESTION NO. 19. *What is the shortest time in which malleable castings can be annealed to produce the best malleable qualities?*

ANSWER. By H. A. Schwartz, manager of research; National Malleable Castings Co., Cleveland. A strictly correct reply would probably be infinity since, speaking broadly, every means of accelerating graphitization is detrimental to the ductility of the product. A strictly logical conclusion thus would indicate that, the slower the process, the better the product, hence the best product can be made only in infinite time.

Graphitization proceeds more rapidly and less completely the higher the temperature. Its commercial execution is accomplished by holding the metal for a time at a temperature well above A_1 and then cooling in such a manner that the metal shall be at or near A_1 for a sufficient time to complete the reaction.

Time will be saved by executing the preliminary treatment at the highest practicable temperature. However, the higher temperature the coarser the temper carbon granules and the less the strength and ductility, consequently

there is a limit to the time to be saved by raising the initial temperature. Commercial opinion varies as to the highest safe temperature. Some manufacturers feel it unsafe to go above 1500 degrees Fahr.; others go as high as 1850 degrees Fahr. The former makes for quality, the latter for speed. A temperature of 1600 or 1625 degrees Fahr. is perhaps a conservative middle course.

Commercial practice varies with respect to the completion of the reaction. Some metallurgists cool slowly through the critical range; others feel it better to maintain a constant temperature just below A_1 for some time. The latter course, no doubt, saves time but requires very accurate control to avoid passing above A_1 by accident.

Graphitization can be accelerated by an increase in carbon or silicon, both of which deteriorate the quality of the metal when present in too large an amount. Here again speed is had at a sacrifice of quality.

In the early days, using carbon and silicon in amounts now considered excessive, it was very common to occupy 7 days for the annealing cycle. The recent improvements in malleable castings were accomplished in part by reductions in carbon and occasionally silicon and by greater annealing precautions. The time for annealing has thus risen for two reasons.

The writer has frequently annealed metal in small commercial furnaces in 3½ to 4 days. The metal was never of superior quality and frequently very unsatisfactory and this attempt to hasten deliveries was definitely abandoned.

The design of heating furnace also affects the answer since uniform rapid heating is difficult to attain in large furnaces; but such furnaces are economical of fuel and space.

Under commercial conditions and on an operating scale, the writer would regard with suspicion metal annealed in less than 7 days and would not regard 10 or 11 days as excessive.

Where particular importance is attached to ductility and to machineability, without sacrifice of strength; still longer times may be called for. A single piece, of inferior quality, could no doubt be produced experimentally in around 50 or 60 hours.

QUESTION NO. 20. *What are the causes of warping in the heating and cooling of steel?*

QUESTION NO. 21. *In answering Question No.* 3, *which appeared in the January issue of* TRANSACTIONS, *C. Craine, Mattison Machine Works, Rockford, Ill., refers to the fact that cast iron gage bases were treated at temperature from* 600 *to* 900 *degrees Fahr. for a period of* 12 *to* 18 *hours, and were allowed to cool in the furnace, the theory being that this treatment obviated the necessity for the ageing of the castings. What effect, if any, would have been produced had the castings been heated to a very much higher temperature, say* 1600 *degrees Fahr.? In view of the fact that certain of the castings referred to had to be twice re-treated in a similar manner for* 12 *to* 24 *hours, before overcoming all effects of warpage, the value of the treatment seems doubtful. What assurance is there that some of the castings which were treated but once, ought not to have been treated twice, or even three times?*

ANSWER. By H. A. Schwartz, manager of research, National Malleable Castings Co., Cleveland. Any casting develops internal stresses due to

unequal cooling and retains its final shape due to a balance between opposing internal stresses. On machining off stresses material, the equilibrium is disturbed and the casting warps. Ageing, heating, vibration or the removal of metal with light cuts on opposite sides all serve as a means of slowly relieving internal stresses and hence of preventing warping on subsequent machining. It would seem that to be effective as an eliminator of casting strains, the temperature reached in heat treating must be sufficiently high to cause a distinct increase in ductility of the iron. Such an increase is not observed until the metal is heated above 900 degrees Fahr., but the increase in softness with increasing temperature above 900 degrees Fahr. is very rapid. Any temperature above 1400 degrees Fahr. if maintained sufficiently long will cause a resolution of the graphite with possible increase of hardness unless cooling is very slow. At temperatures as high as 1600 degrees Fahr. the metal, if it contains graphite, must be protected from oxygen, or carbon dioxide, else these gases will oxidize carbon, penetrate into the metal first where the graphite was and later along the grain boundaries, oxidize the metal and produce a "rotten" product. In any event the cooling of the metal must be uniform throughout and quite slow.

ANSWER. By C. R. Crain, Mattison Machine Works, Rockford, Ill. It is evident that I have been misunderstood. First let me explain that the treatment in question was not adopted in preference to the "time and weather" method, but as an emergency measure to hasten the conditioning of the castings. The method used, while not to be recommended as standard practice, produced results for us that exceeded our expectations and enabled us to cut the time element considerably.

To carry the castings to a high temperature than 900 degrees Fahr. resulted in a perceptible softening as well as increase in volume. The size and shape of piece to be treated was the deciding factor as to the number of treatments. Small pieces that were not too delicate seldom required more than one treatment. Larger castings of delicate shape were first treated, then rough machined, then reheated and finished. During rough machining operations stresses are usually set up but can be relieved by a second treatment which seldom need be repeated. Close attention and good judgment will be necessary to insure success.

QUESTION NO. 22. Can ghost lines be eliminated by heat treatment?

NOTE. A difference of opinion exists on this subject as shown by the four brief answers submitted with the question. N. B. Hoffman says: Ghost lines can not be broken. The carbon can be recrystallized but the nonmetallics remain. W. J. Merten says: Ghost lines can be eliminated by heating to a very high temperature and cooling to the critical point rapidly. Then heat treat from this point. A. M. Cox says: Ghost lines can be prevented from forming. W. B. Crowe says: Ghost lines can not be eliminated but may be modified.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?

QUESTION NO. 24. What methods can be suggested for brazing high speed sheet steel strips together, preferably during the hardening operation? A spelter of copper, tin, aluminum and borax finely pulverized seems to interfere with the proper hardening. The portion of the tool brazed must maintain a keen edge and have good red hardness.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

EFFECTS OF QUALITY OF STEEL ON CASE CARBURIZING RESULTS. By H. K. McQuaid and E. W. Ehn. Presented at the February meeting of the American Institute of Mining and Metallurgical Engineers.

The investigation was instituted as a result of occasional irregularities encountered in the hardening of carbonized roller bearings. Careful study brought out the fact that the defective pieces could be picked out with the aid of the microscope before hardening. Open-hearth steel invariably proved to be the offender, electric steel giving no trouble. Chemical analysis revealed nothing. The trouble seemed to be due to instability of the pearlite in the hyper-eutectoid region. The trouble was finally traced to the steel process, oxidized or overheated lots always giving rise to trouble.

MAKING A CASE HARDENED CRANKSHAFT. Anonymous, *American Machinist*, Vol. 56, Page 72.

The Franklin Motor Co. is at present carbonizing its crankshafts. The shafts are carbonized 24 hours at 1600 to 1700 degrees Fahr., cooled in the box and reheated for quenching to 1450 degrees Fahr.

CARBURIZING MATERIALS. By H. B. Knowlton, *Forging and Heat Treating*, Vol. 7, Page 590.

The various forms of carburizing are briefly discussed. Wood charcoal, leather, bone, coal and energized carbonizers are taken up in some detail. The results of some experiments in carbonizing are presented along with photomicrographs.

SPECIFICATIONS WHICH DON'T SPECIFY. By C. E. Carpenter, *Forging and Heat Treating*, Vol. 7, Page 587.

Attention is called to the fact that specifications for many technical materials do not insure that the buyer will get the best. It is suggested that specifications for case hardening compounds would as yet prove very unsatisfactory.

ELECTRIC STEEL AND IRON

THE STATUS OF THE ELECTRIC STEEL INDUSTRY. By E. F. Cone, *Iron Age*, Vol. 109, Page 85.

There are at present 388 electric melting furnaces in this country, 33 being installed last year. The sales figures of the various makes of furnaces are given together with information on their location.

MANGANESE STEEL MADE IN THE ELECTRIC FURNACE. By L. J. Barton, *Iron Age*, Vol. 109, Page 4.

Until very recently manganese steel was made in the converter. Electric manganese steel has proven much superior to converter-made stock. Directions for melting practice are given. Manganese steel ordinarily contains 11 to 13 per cent manganese and 1.10 to 1.30 per cent carbon. The steel as cast is very brittle, but after a heat treatment consisting of quenching the steel from 1800 degrees Fahr., great toughness is obtained.

THE MANUFACTURE OF CHROMIUM BALL BEARING STEEL IN THE HEROULT FURNACE. By F. T. Sisco, *Chemical and Metallurgical Engineering*, Vol. 26, Page 71.

From the results of five years experience in melting high carbon, high-chrome steel the best procedure has been worked out and is presented in this article. Methods of detecting hair-line seams are given.

ELECTROLYTIC IRON A COMMERCIAL PRODUCT. By Bradley Stoughton, *Iron Age,* Vol. 109, Page 32.

Two electrolytic iron plants are at present in operation, one at Hawthorne, Ill., and one at Grenoble, France. The properties of electrolytic iron are such as to make it very useful for any severe drawing or stamping operations. A great future is predicted for its use. Curves and data giving the tensile and anticorrosive properties are given.

MACHINING PROBLEMS

CUTTING FLUIDS. By E. C. Bingham, Bureau of Standards, Technologic Paper No. 204.

The function of the fluids used in cutting operations were studied in detail and the various fluids commonly used such as lard oil, mineral oil, soap solution, etc., investigated. As a result of the studies, recommendations are made as to the proper use of the various fluids investigated.

METALLOGRAPHY AND RESEARCH

INTERCRYSTALLINE FRACTURE IN STEEL. By D. Hanson, *Transactions* of the Faraday Society, Vol. 17, Part 1, Page 91.

Several examples of intercrystalline fracture in cold worked low and medium carbon steel and quenched carbon steels are given. In the cold worked steels corrosion may have played some part in the cracking but the main cause in all of the cases was excessive internal strains. The article is illustrated with numerous photomicrographs.

THE MECHANISM OF THE FAILURE OF STEEL UPON AND AFTER HARDENING. By G. W. Green, *Transactions* of Faraday Society, Vol. 17, Part 1, Page 139.

The causes of stressing and subsequent failure suggested are: (a) Increased volume change; (b) decreased molecular mobility; (c) instability due to incomplete phase change and the presence of residual austenite; (d) variable volume change due to heterogeneity; and (e) the tendency to warp on quenching due to contraction of the outer skin.

CONSTITUENTS OBSERVED IN TUNGSTEN AND MOLYBDENUM STEELS. By A. Portevin, *Revue de Metallurgie,* Vol. 18, Page 713.

A critical metallographic inspection is made of annealed tungsten steels containing carbon 0.1 to 0.4 per cent and tungsten 5.0 to 7.5 per cent. As a result of this inspection, four constituents are identified, an iron tungstide, a carbon tungstide, a troostite of tungsten and a complex ferritic Fe_2W constituent. Attention is called to the resemblance between the constituents of tungsten and molybdenum steels.

THE COLLOIDAL STATE IN METALS AND ALLOYS I—MOLTEN METAL. By J. Alexander, *Chemical and Metallurgical Engineering,* Vol. 26, Page 54.

The relation of the colloidal state to the "amorphous" state in metals is pointed out and evidence obtained in the ultramicroscopic study of glass is applied to metals.

THE COLLOIDAL STATE IN METALS AND ALLOYS II—CRYSTALLIZATION. By J. Alexander, *Chemical and Metallurgical Engineering,* Vol. 26, Page 119.

This second article takes up the phenomena of crystallization and plastic deformation from the colloidal standpoint.

RESEARCH IN THE STEEL INDUSTRY. By J. A. Mathews, *Mining and Metallurgy,* No. 180, Page 11.

The function of the research laboratory is outlined and research programs discussed. Numerous instances of the value of research in the steel industry are given from the author's personal experience.

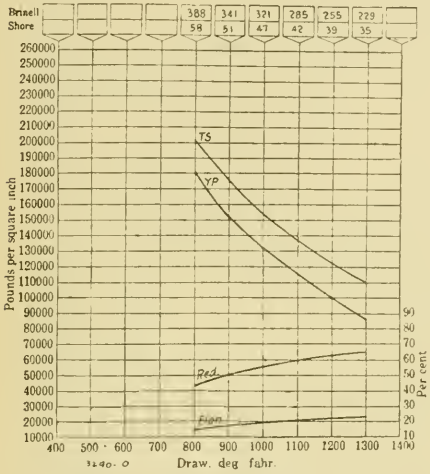
PHYSICAL PROPERTIES OF STEEL

EFFECT OF TIME IN REHEATING QUENCHED MEDIUM-CARBON STEEL BELOW THE CRITICAL RANGE. By C. R. Hayward, D. M. McNiel and R. L. Presbrey. Presented at the February meeting of the American Institute of Mining and Metallurgical Engineers.

Bars of 0.44-0.48 per cent carbon steel were water quenched from 850 degrees Cent. and drawn for periods ranging from five minutes to four hours at temperatures varying from 300 to 600 degrees Cent. Five minutes at 300 degrees Cent. was sufficient to make perceptible changes in the strength and hardness of the metal. Tempering at 400-500 degrees Cent. increased the ductility without lowering the strength the same relative amount. One hour heatings seem to be long enough to accomplish the tempering completely and even 30 minutes is sufficient at 400 degrees Cent.

FRACTURE TESTS ON CONSTRUCTION STEEL AND THE KRUPP "DAUERSCHLAGPROBE." By F. Rittershausen and P. Fischer. *Stahl und Eisen*, Vol. 41, Page 221.

As a result of approximately 3500 tests, a relationship was established between the capacity for resistance in the Krupp machine and the yield point. Tests were made on plain carbon, nickel, nickel-chrome, manganese and silicomanganese steels.



Physical property chart of S. A. E. No. 3240 quenched in oil

REPORTS OF DIVISIONS OF STANDARDS COMMITTEE. *Journal* of the Society of Automotive Engineers, Vol. 9, Page 383.

In the report of the Iron and Steel Division, (pages 392-422) in addition to proposed changes in specifications, valuable information on the effect of heat treatment on the physical properties of the following steels is given: 1020-1045, 2320-2340, 3120-3140, 3220-3250, 3325-3335, and 3435-3450. The information is given in charts a typical one being shown. Information on heat treatment and uses is also given on steel 5120-5150, 5210, 6120-6195 and 9250-9260.

THERMOCOUPLES

LIFE TESTS OF PLATINUM; PLATINUM-RHODIUM THERMOCOUPLES. By C. O. Fairchild and H. M. Schmitt, *Chemical and Metallurgical Engineering*, Vol. 26, Page 158.

Tests made on American and English noble metal thermocouples showed that they deteriorated noticeably when exposed to temperatures of 1250 to 1450 degrees Cent. The English couple was more at fault in this respect than the American. Experiments showed this variation to be due to volatilization of impurities, especially iron. Samples of English thermocouples tested at a later date and made of purer material showed a marked improvement in ability to withstand deterioration at high temperatures.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

AMES, HARVEY C., (Jr-2), 217 Birchwood Ave., Davenport, Iowa.
BALDWIN, R. C., (M-2), Stanley Rule & Level Co. New Britain, Conn.
BECHNELL, EDWIN, (Jr-2), 202 Second Avenue Moline, Ill.
BEEBE, G. E., (S-2), 1231 West Ninth St., Cleveland, O.
CAMPION, D. C., (M-12), 5003 Holcomb, Detroit, Mich.
DAHLEN, JOHN, (M-11), 1807 South Fifth St., Rockford, Ill.
DIETRICH, F. E., (Jr.-2), 2915 Eleventh Avenue, Moline, Ill.
DOERR, PAUL C., (A-2), 54 Meridith Street, Springfield, Mass.
DREVER, HORACE, (M-2), Electric Furnace Construction Co., Philadelphia, Pa.
EGEBERG, BIRGER, (M-3), Stavanger Electro, Staalverk, Stavanger, Norway.
GAILLARD, S. G., (M-2), American Pulley Co., Philadelphia, Pa.
HIGGINS, GEORGE H., (M-1), Burd Ring Co., Rockford, Ill.
HIGGINS, RAYMOND L., (M-2), Mahr Mfg. Co., Minneapolis, Minn.
HOENSHEID, ANTHONY, (M-11), Detroit Twist Drill Co., Detroit, Mich.
HOPPELL, GEORGE C., (M-1), 5142 Spruce Street, Philadelphia, Pa.
LEWTON, ROSS E., (M-2), Studebaker Corp. Plant 2, South Bend, Ind.
LOVE, W. D., (A-2), Atlas Crucible Steel Co. Philadelphia, Pa.
MACKINTOSH & HEMPHILL CO. (S-2) Pittsburgh, Pa.
MCTURK, M. H., (M-2), 314 Penna Bldg., Philadelphia, Pa.
MESTA MACHINE CO., (S-2), Pittsburgh, Pa.
MORIN, L. H., (M-2), Soss Mfg. Co., Grand Ave. & Bergen St., Brooklyn, N. Y.
NOLING, M. N., (M-1), 2004 E. State St., Rockford, Ill.
PECK, C. A., (M-2), 316 E. Monroe St,, South Bend, Ind.
PHILLIPS, ARTHUR., (M-1), Yale University, Hammond Laboratory, New Haven, Conn.
RALSTON, A. L., (A-2), 1734 Lafayette Blvd., Detroit, Mich.
RICHARDSON STANLEY A., (M-2), Madison & Robey Streets, Chicago, Ill.
RITTS, H. L., (M-1), 6545 Epworth Blvd., Detroit, Mich.
ROWAN, HUGH, (M-1), 178 Northwestern Ave., Milwaukee, Wis.
RUBY, WM. J., (M-2), 2174 E. Warne Avenue, St. Louis, Mo.
SPADE J. H., (A-2), Ludlum Steel Co., Philadelphia, Pa.
ST. LOUIS PUBLIC LIBRARY, Olive 13th & 14th St., St. Louis, Mo.
STITES, S. T., (M-1), 623 Oak Street, Rockford, Ill.
STOKES, F. J., (M-1), Tabor Rd. & Cedar Grove Sta., Philadelphia, Pa.
STUMPF, G. A., (M-2), 210 Smith Ave., Lansing, Mich.
SULLIVAN, JOHN H., (M-1), Chicopee High School Chicopee, Mass.
SWENSON, C. E., (M-1), Tarkington Motor Co., Rockford, Ill.
THELEMAN, R. T., (Jr-2), 242 Hancock Ave., Davenport, Iowa.
TITUS, W. E., (A-2), 316 North Third St., Philadelphia, Pa.
TURNER, JOHN J., (M-2), 128 Chandler St., Worcester, Mass.
TUTHILL LEROY M. (M-3), 546 Adams Ave., Scranton, Pa.
UNITED ENGINEERING & FOUNDRY C., (S-3), Pittsburgh, Pa. Attention of F. C. Biggert, Jr.
VOLKOFF, VLADIMIR, (Jr-1), 199½ Eight Street, Troy, N. Y.
WALDRON R. E., (M-2), 5033 Vancouver Ave., Detroit, Mich.
WILLIAMS C., (M-2), 432 West Penna St. Germantown, Pa.

CHANGES OF ADDRESS

BARTLETT, J. W., (M-5)—from Dunn Edge Tool Co., Oakland, Maine, to 596 Jarnis St., Toronto, Ont., Can.
BAYLESS, RAY T., (M-1)—from Jas. H. Herron Co., to 2185 Edgewood Rd., Cleveland, Ohio.
BELIAEFF, S. S., (M-1)—from U. S. High Speed Steel & Tool Co., Green Island, N. Y., to P. O. Box 44, Troy, N. Y.
BLUMBERG, HARRY—from Illinois Steel Co. to 1424 W, 14th St., Chicago, Ill.

BOYER, S. H.—from 1065 Hubbard Ave. to Studebaker Corp., Detroit, Mich.
BRETSCH, A. W., (M-12)—from 1234 Hamilton Ave. to 1234 Harding Ave., Detroit.
BROOKS, CHAS. A., (M-6)—from 2139 Gilles St., Wilmington, Del., to 1393 Broadway, Rennselaer, N. Y.
BURRILL, PERCY J., (A-11)—from 114 Arlington St. to 44 Lincoln Apts., Youngstown, Ohio.
BURROUGHS, J. T., (A-3)—from 3063 West Blvd., to 4329 W. 23rd St., Cleveland.
CALER, J. H.—from Vanadium Alloys St. Co., to 414 Union Bldg., Cleveland.
COLEMAN, JOHN J.—from 79 Adelaide St. W. to 449 St. Paul St. W., Montreal, P. Q., Canada.
CONNER, WM. G., (M-4)—from N. 11th St., Rochelle, Ill., to DeKalb, Ill.
DANIELS, F. C. T., (M-2)—from Beech Glen, Wheeling, W. Va., to R. D. No. 4, Elm Grove, W. Va.
DEMPSEY, H. B., (A-8)—from 253 Broadway to 21 Park Rd. W., New York City.
DISNEY, J. A., (A-12)—from 1326 E. Woodbirdge St. to 10201 E. Jefferson Ave., Detroit, Michigan.
GILTINAN, D. M., (M-12)—from 27 Dunbar St. to 1223 Virginia St., Charleston, W. Va.
GRANGER, D. J., (M-1)—from 1518 S. 48th Ave. to 4725 W. 15th Pl., Cicero, Ill.
GREEN, C. T. M., (M-2)—from A. Hankey Co., Rochdale, Mass., to 100 Burks St., Easton, Pa.
HANDY, H. E., (M-3)—from Washington Steel & Ore Co., Washington, D. C., to 773 Elmwood Avenue, Providence, R. I.
HAYDOCK, JOHN, JR., (M-9)—from 111 Broadway, New York City, to Niles Bement Pond Co., Pond Works, Plainfield, N. J.
HENLEY, W. A., (M-12)—from U. S. N. O. P. S. Charleston, W. Va., to Woodstock, Md.
HODGE, E., JR., (A-2)—from Pittsburgh Knife & Forge Co., Pittsburgh, to Box 466, Coraopolis, Pa.
HOLLERITH, C. B., (M-11)—from 3515 N. Penn Apt., to 20 W. 34th Apt F., Indianapolis, Ind.
HOWLAND, J. A., (A-4)—from 635 Waveland Ave., Chicago, to 555 Beaufait Ave., Detroit, Mich.
HOWLAND, WM. A., (M-1)—from 1217 Maple Ave. to 1316 Lake St., Evanston, Ill.
HUMMELL, A. S., (M-4)—from Bloomsbury, N. J., to 122 N. Third St., Easton, Pa.
KRONFELD, G. L., (M-12)—from 1321 Oliver Bldg., to Vulcan Crucible Steel Co., 493 Union Arcade, Pittsburgh, Pa.
MAGILL, B. H.—from American Locomotive Co. to 103 Nott Terrace, Schenectady, N. Y.
MERRIOTT, WALLACE, (M-11)—from Weekes-Hoffman, Inc., to New Process Gear Corp., Syracuse, N. Y.
MOORE, J. W., (A-4)—from 1404 Oliver Bldg., Pittsburgh, Pa., to Hoskins Mfg. Co., 1445 Laughlin Avenue, Detroit, Mich.
PARDEE, H. A., (M-12)—from Crucible Steel Co. of America, Pittsburgh, Pa., to Box 11, Grand Central Station, New York City.
PEDERSEN, P. P.—from 4126 Zenith Ave. to 4917 S. York Ave., Minneapolis, Minn.
RILEY, ROBT., (M-3)—from 6 Atwood St. to 11 Priscilla Ave., Olneyville, Sta., Providence, R. I.
ROBINSON, S. R., (M-4)—from Sandusky Foundry & Mach. Co. to 409 W. Washington St., Sandusky, Ohio.
SCHMID, M. H., (M-1)—from United Alloy Steel Corp. to 501 11th St. N. W., Canton, Ohio.
SEAMON, W. M., (M-10)—from 41st & Willow St. to 2334 Buxonia Ave., Pittsburgh, Pa.
SHERMAN, A. H.—from 120 Broadway to Industrial Specialties Inc., 52 Vanderbilt Avenue, New York City.
SOWDER, STANLEY, (M-3)—from 6546 Second Blvd. to 80 Davenport St., Detroit, Mich.
STRANAHAN, L.—from Standard Parts Co. to Cleveland City Forge & Iron Co., E. 45th & Lakeside, Cleveland, Ohio.

SURTEES, ROBT. E., (M-2)—from 1622 Hazelwood Ave. to 2919 Anderson, Detroit, Mich.
THOMAS, R. W.—from 74 S. Meade St. to 519 Carey Ave., Wilkes Barre, Pa.
WELLMAN, V. M.—from 1105 Chester Ave. to 1224 Oregon Ave., Cleveland, O.
WHITE, F. G., (M-11)—from Y. M. C. A. to the University Club, Grand & Washington Avenues, St. Louis, Mo.
WILKINS, CHAS., (M-3)—from 4001 Drexel Blvd. to 833 E. 65th St., care Mr. Stinchfield, Chicago, Illinois.

MAIL RETURNED

ALBERS, L., JR., 175 Bleecher St., Brooklyn, N. Y.
ALLEN, R. D., (M-3), Lab. Studebaker Corp., South Bend, Indiana.
MORGAN, A. B., (M-12), 107 Columbia Avenue, Charleston, W. Va.
NELSON, JOHN, Royal Oak, Michigan.
SEMONS, FRANK, (M-4), Spring Perch Co., Stratford, Conn.
SMITHIES, M. W., (M-3), Atlas Ball & Co., 4th & Glenwood Sts., Philadelphia, Pa.
TISDALE, N. F., (M-3), 47 Johnson Street, Springfield, Mass.
WILLIAMS, R. W., (M-8), Sheldon Axle & Spring Co., Wilkes Barre, Pa.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

ROCKFORD CHAPTER

THE *B-C-A News* published monthly by and for the employes of Barber-Colman Co. has a very interesting account of the activities of the Rockford Chapter in the February number. It is as follows:

"Heat treating as an art has been practiced for several thousand years; its importance in industrial operation is of more recent date and seems to be closely connected with the development of the automobile. Whatever the causes of its prominence are or may be, one fact stands out pre-eminent: the seriousness with which the subject is deliberated upon in literature in societies connected with the art and not the least in industry itself.

"The progress of heat treatment is nothing short of astonishing. Once it was an obscure not to say dark art, guarded with great secrecy and passed on only by word of mouth. Today science is its staunchest ally and the practice of heat treating is regulated by organized facts to a point of precision.

"As is the case of any progressive art, not all artisans are able to keep step with the rapid development. Realizing this fact it occurred to a group of men who were actively engaged or connected with the art, that they should unite and with combined efforts venture into an educational campaign for the betterment of the art and its practice.

"These first, although not exactly feeble, attempts proved to be steps in the right direction and developed later on in what is known today as "The American Society for Steel Treating," an organization comprising over 3000 individual members and over 30 chapters located in all parts of the United States, with headquarters in Cleveland, Ohio.

"One of the youngest chapters in the national organization was founded recently in Rockford and is known as the Rockford Chapter of the American Society of Steel Treating. O. T. Muehlemeyer is chairman, O. H.

"These with the board of directors, Charles Cotta, A. H. Hemering, C. R. Crain and John F. Frederick are the officers.

"The first regular meeting was held in December at the Nelson hotel with an attendance of about 100 representing almost the entire steel using industries of the city of Rockford. W. H. Eisenman, National Secretary, was the speaker of the occasion. His subject 'Heat Treating, its Past, Present and Future,' very aptly delivered, held the audience from start to finish and caused many to apply for membership. Previous to the meeting Mr. Eisenman visited our plant.

"The second or January meeting was featured by O. T. Muehlemeyer's paper on 'Hardening Practice,' which was very friendly received. In the course of this paper it was pointed out that the public accepts automobiles, airplanes, sewing machines, cash registers and thousands of other commodities as accomplished facts without thinking much, if any, about the important part heat treating plays in their manufacture. Later on, equipment and operation of a heat treating plant was described more in detail. That this paper was nontechnical made it all the more interesting and, hopefully, serves as an instance for further efforts.

"The third meeting will be held this month—on the thirteenth of February, to be exact—and will be, as we are confidentially informed, of more than passing interest. Two speakers, one of them F. P. Gilligan, President of the National Society, have kindly consented to make their appearance before the Rockford public and judging by past experiences a large audience is to be expected. The active membership of the local chapter has so far reached 50 with one sustaining member, the Barber-Colman Co.

"The society has lately published a small pamphlet, 'A Successful Society for Successful Men,' from which are copied the following paragraphs:

"The purposes of the American Society for Steel Treating are: 1. To promote the arts and sciences connected with the heat treatment of steel, and the study of subjects relating to manufacture, properties and the uses of iron and steel.

"2. To hold meetings in the chapters of the Society—at present there are 32—for the reading and discussion of papers bearing upon processes, instruments, equipment, apparatus, etc., employed in practical and research work connected with the art.

"3. To collect, publish and disseminate technical and practical knowledge for the improvement of conditions in connection with heat treatment of steel.

"4. To closely unite those engaged in the executive, technical and practical branches of the same.

"5. To collect worth-while ideas and improved methods for its members.

"A worthy object, worthy of the best efforts of all interested in steel and its uses, may the Rockford Chapter live and blossom into fulfillment of these high ideals."

SOUTH BEND CHAPTER

The South Bend Chapter held its February meeting on Tuesday, Feb. 14 at the Y. M. C. A. A dinner meeting was held honoring F. P. Gilligan, National President.

The first speaker was Pat Dwyer, engineering editor of *The Foundry*. Mr. Dwyer spoke for one hour and kept the house in an uproar by rapid fire yarns, intermingled with real foundry dope.

The next speaker was Mr. Gilligan whose subject was "What Happens

to Steel When it is Quenched." It would be difficult to really express the appreciation of Mr. Gilligan's lecture. It was far above anything the chapter has yet heard and it was brought home to the shopmen who are still talking about it.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held the fourth of its series of meetings on "The Manufacture, Treating, and Testing of Steel" in the Battery building of the Bethlehem Steel Co., Bethlehem, Pa., on Feb. 13. This meeting featured two subjects: "Castings" and "Forgings."

H. G. Walton of the Bethlehem Steel Co. gave the talk on castings, describing foundry practice from the making of the patterns to the cleaning and inspecting of the finished castings. Mr. Walton discussed the characteristics of various alloy steel castings, the different methods of melting for pouring, etc., the heat treating of castings and gave a list of many types of castings and their uses.

F. P. Martin, superintendent of the forge and heat treating departments of the Ingersoll-Rand Co., and a member of the executive committee of the Chapter gave the talk on forging. Mr. Martin's talk dealt with modern forge shop practice in general. Particularly interesting was the description of the forging of drills or drill steels used for rock drilling.

Both talks were very well presented and it was apparent that both speakers were thoroughly at home with their subjects. Much interest was shown, as usual, in the exhibit, maintained by the Bethlehem Steel Co. at the Battery building and this alone was considered worth the effort in attending the meeting.

TRI-CITY CHAPTER

The regular January meeting of the Tri-City Chapter was held on Jan. 26 at the Davenport Chamber of Commerce. F. P. Gilligan, National President of the Society, gave a very interesting talk on the subject "Quality First," in use and the hardening of tool steel. Mr. Gilligan made his talk very plain, first explaining the subject in metallurgical terms and then in plain English so everybody could understand it. After Mr. Gilligan's talk there was practically no discussion because he had explained everything so thoroughly that there was nothing to discuss. His talk was illustrated with slides.

Motion pictures of the manufacture of steel for sheets and plates, from the Bureau of Mines, Pittsburgh, Pa., were next shown. These pictures were of great interest to all of the members present.

The February meeting of the Tri-City Chapter was held at the Davenport Chamber of Commerce on Feb. 17 when John F. Keller, professor of metallurgy, Lewis Institute, Chicago, presented a paper on "Steel, its Selection and Treatment." This interesting illustrated lecture also included the demonstration of the spark method of selecting iron and steel on a live emery wheel. The meeting was considered one of exceptional value and created a large amount of discussion.

DETROIT CHAPTER

The first meeting of the Detroit Chapter was held in the Board of Commerce rooms on Feb. 13. A round table discussion on ring gears was the principal topic of the evening and created extensive comment and discussion. The questions sent out from the National Office for the "Question

Box" were also presented and discussed. Some interesting discussion resulted.

The second meeting of the month was held on Feb. 27 at the same place. F. H. Helrigel of the Motor Products Co. presented a paper on "Working Sheet Steel." Mr. Helrigel has made a very extensive study of this phase of the subject and had a very interesting paper.

W. P. Woodside, Executive Chairman of the Convention Committee, has made announcement of the assignments of the committee to handle the details of the Convention. These committees appear on another page of this issue of TRANSACTIONS.

NORTH WEST CHAPTER

The fourth lecture in the educational course on the elements of metallurgy and heat treatment being conducted by the North West Chapter was given on Monday evening, Jan. 30 in the rooms of the Manufacturer's Club. Chester S. Moody, Minneapolis Steel & Machinery Co. discussed "Cast Iron" and L. H. Berry, Western Crucible Steel Castings Co., discussed "Cast Steel." Briefs of these lectures, summarizing the issues presented by the speakers, were ready for distribution that evening.

PHILADELPHIA CHAPTER

The February (Big) meeting was held on Friday evening, Feb. 24 at the Engineers' Club. The speakers were National President F. P. Gilligan, Dr. John A. Mathews, president Crucible Steel Co. of America, Pittsburgh, and Richard Spillane, *Philadelphia Public Ledger*. The complete write-up of this meeting will be published in the April issue of TRANSACTIONS.

BRIDGEPORT CHAPTER

The Bridgeport Chapter held a very fine meeting at the Chamber of Commerce on Tuesday, Jan. 31. The first speaker of the evening was C. M. Blackman, foreman, of the heat treating department of the Colt's Patent Firearms Mfg. Co. A. H. d'Arcambal, metallurgist, Pratt & Whitney Co., Hartford, Conn., also presented a paper.

About 65 members and guests were in attendance and practically all of them participated in the discussion which followed the presentation of the excellent papers.

SYRACUSE CHAPTER

S. D. Marshall of the Endicott Forge Co. addressed the Syracuse chapter at its February meeting at Yates Hotel on the subject of "Drop Forgings." Mr. Marshall's wide experience in this line as well as his ability to present his subject in an interesting manner made the meeting a very successful one. A buffet luncheon was served at the close.

RHODE ISLAND CHAPTER

The February meeting of the Rhode Island Chapter was held in the rooms of the Providence Engineering Society on Feb. 12. The speaker of the evening was R. H. Schaffer, superintendent of the Textile Finishing Machine Co., Providence, R. I. He chose as his subject "Practical Hardening Room Practice." Mr. Schaffer was the first representative of a Providence firm to address the chapter and the excellent manner in which he presented his subject and the amount of discussion created was highly pleasing.

CHARLESTON CHAPTER

Fifty-five members of the Charleston Chapter assembled at the Kanawha

Hotel on Feb. 7 and heard a very interesting paper by A. F. Mitchell on "Heat Treatment of Carbon Steel." A lively discussion took place on Mr. Mitchell's paper as well as a discussion on the manufacture of tool steel.

CHICAGO CHAPTER

The Chicago Chapter held its regular meeting on Feb. 9 when they entertained the National President, F. P. Gilligan, who gave an illustrated talk on "Steel and Its Properties." The lecture was presented in a most practical manner and was very pleasing to the 200 members and guests in attendance.

The next meeting will be held on March 9 and will be devoted to the discussion of practical questions. Prof. John F. Keller, consulting metallurgist and professor of metallurgy at the Lewis Institute, Chicago, will open the discussion with some original ideas on "Why Steel Warps."

ST. LOUIS CHAPTER

The February dinner and meeting of the chapter was held at Hotel Claridge on Friday, Feb. 10. The speaker of the evening was W. R. Chapin, director of the testing department of E. C. Atkins & Co., Indianapolis, upon the subject "Properties of Some Steels in the Hardening Range." Mr. Chapin's excellent presentation of the subject was most thoroughly enjoyed by all present. The paper is published elsewhere in this issue of TRANSACTIONS.

BOSTON CHAPTER

The Boston Chapter enjoyed one of the best meetings it has had for some time at the Boston City club on Feb. 10. The paper of the evening was presented by Z. L. Sault, treasurer of the New England Annealing & Tool Co. on the subject of "Heat Treating Experiences." Mr. Sault spoke in a very interesting manner upon the experiences he had encountered and gave those present the benefit of his extensive knowledge and dealing with all kinds of steel.

BUFFALO CHAPTER

The Buffalo Chapter had its regular meeting in the rooms of the Buffalo Engineering society, Iroquois Hotel on Wednesday, Feb. 15. The National President, F. P. Gilligan presented a paper which proved to be especially interesting, and the amount of discussion brought forth was decidedly satisfactory.

WASHINGTON CHAPTER

The February meeting was held in the auditorium of the New Interior Department building on Feb. 17. Francis B. Foley, metallurgist, Bureau of Mines, Minneapolis Station, Minneapolis, Minn., was the speaker of the evening and spoke on "The Annealing and Hardening of Steel." Mr. Foley covered the fudamental relations that must be considered in the annealing and hardening of steel. This involved the means of practical application of the theories of heat treatment and was illustrated by some of the speaker's own investigations into the effect of methods of heat treatment as applied to various materials.

CINCINNATI CHAPTER

The Cincinnati Chapter held a splendid meeting at the Ohio Mechanics

Institute on Feb. 14. Prof. H. F. Moore of the University of Illinois, Urbana, Ill., presented his paper on "The Fatigue, or Progressive Failure of Metals." Approximately 125 were in attendance, the members of the local section of the American Society of Mechanical Engineers being present by invitation.

WORCESTER CHAPTER

The January meeting of the Worcester chapter was held at the National Metals Trades association on Jan. 31. J. C. Spence superintendent of the machine division of the Norton Co. was the speaker of the evening and chose as his subject "Grinding of Steel." Mr. Spence discussed the difficulties encountered in grinding steel; proper methods of procedure; precautions; various grades of finish; grinding cracks, and their cause and avoidance.

The Worcester Chapter held its regular meeting on Feb. 14 in the Y. M. C. A. building. The first speaker of the evening was Z. L. Sault, treasurer of the New England Annealing & Tool Co. of Boston, Mass., and also the secretary of the Boston Chapter. Mr. Sault took as his subject "The Experience of 30 Years in the Heat Treatment of Steel," which included methods for annealing, hardening and heat treating carbon tool steel, high speed steel and low carbon steel for pack hardening. Mr. Sault's talk was a very practical one and met with most general approval of all present.

The second speaker of the evening was F. J. Evans of the Surface Combustion Co. on the subject of "Heat Application." Mr. Evans pointed out that one of the most essential factors, if not the most essential factor, in the heat treatment of steel is the furnace, or the means of heat application. Too often the furnace has been looked upon as merely an enclosure of fire-brick with a fuel—any fuel—applied at some point. He pointed out that accurate heat treatment was absolutely dependent upon correct heat application which means a furnace designed and equipped along engineering principles.

SPRINGFIELD CHAPTER

On Feb. 4 the members of the Springfield Chapter and its friends visited the Springfield Armory plants where the famous Springfield army rifle is made. Mr. Woods, metallurgist at the armory was in charge of the visitation and certainly made the trip a real treat.

The regular February meeting of the Chapter was held at the Chamber of Commerce rooms on Friday evening, Feb. 17. J. C. Spence, works manager of the Norton Co., Worcester, Mass., gave a very interesting and instructive talk on "The Grinding of Tools and Other Heat Treated Materials." Mr. Spence told briefly of the history of grinding and then of some of the troubles encountered in daily practice giving the reasons and cures for them. He also showed a number of lantern slides of various grinding machines, both regular and special.

At the close of the talk an informal discussion was held around a large table on which Mr. Spence showed a large number of interesting samples. About 50 members and friends were present, which was encouraging inasmuch as the meeting was held on the coldest day of the year.

CLEVELAND CHAPTER

The Cleveland Chapter held its regular meeting at the Cleveland Engineering Society's rooms, Hotel Winton, Friday evening, Feb. 24. The paper of the evening was presented by Francis B. Foley, of the Bureau of

Mines, North Central Experiment Station, Minneapolis, Minn., on the subject of "Industrial Pyrometry." Mr. Foley has done extensive research work in pyrometry and his talk was full of practical suggestions and interesting details.

The March meeting will be held on March 31, on the same date as the meeting of the nominating committee. The members of the committee have consented to present short talks before the chapter. D. W. McDowell, chief inspector of Jones & Laughlin Steel Co., and secretary of the Pittsburgh Chapter will speak on the "Testing of Steel Plates." W. J. Priestley, superintendent of the United States Naval Ordnance Plant, Charleston, W. Va., and chairman of the Charleston Chapter will present an illustrated talk showing slides of the plant and various methods of manufacture of armor plate. Chester S. Moody, metallurgist of the Minneapolis Steel & Machinery Co. and the first chairman of the Northwest Chapter will present a paper on a "Tractor Gear Problem." H. C. Goodwill, superintendent of dies, R. Wallace & Sons Mfg. Co., Wallingford, Conn., and chairman of the New Haven Chapter will speak on the subject of "Hardening of Dies." Carl Schumann, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, and former secretary of the Chicago Chapter will speak on the "Relationship of the Mechanical Engineer to the Laboratory."

TORONTO CHAPTER

The Toronto Chapter of the society held its February meeting on Feb. 16 in the Mining Building of the University of Toronto. F. P. Gilligan, president of the Society presented an illustrated lecture on steel that met with quite hearty approval by the large number in attendance. W. H. Eisenman, National Secretary, was also present and gave an outline of the progress the society has made during the past year.

SCHENECTADY CHAPTER

The regular meeting of the Schenectady chapter was held on Tuesday evening Feb. 28 in the metallurgical laboratory of the American Locomotive Co. J. V. Emmons, National Treasurer of the American Society for Steel Treating, and metallurgist of the Cleveland Twist Drill Co., Cleveland, presented an illustrated lecture on "Effect of Structure Upon Machining of Tool Steel." Mr. Emmons' entertaining lecture was very highly appreciated and enjoyed.

As a special added feature explanations and demonstrations as to how steel is tested were given. The entire equipment of the metallurgical laboratory was operated for the benefit of members and friends of the society. There was a demonstration of how steel is analyzed, how the physical measurements are obtained, the effect of etching and how microphotographs are taken. Altogether the evening was a decided success.

HARTFORD CHAPTER

At the January meeting of the local chapter, held on Jan. 5 in Hartford, H. J. French of the Bureau of Standards, Washington, described the purposes of the bureau and some of the problems which the bureau has worked out. Investigations of the strength of steels at temperatures higher than atmospheric, and the heat treatment of molybdenum steels were described at some length, and slides and motion pictures illustrating the equipment and some of the activities of the heat treatment section were shown.

Dr. R. W. Woodward, formerly of the Bureau of Standards, but now metallurgist with the Whitney Mfg. Co., told of a somewhat uncommon effect he had observed in the heat treatment of chain links recently. A single lot of links which came through the regular heat treatment showed a blistered surface, as though badly scaled. Examination proved that only a very slight superficial scale was present, however. Evidence obtained by a thorough investigation indicated that the atmospheric conditions in the furnace that produced the blistered links were at fault, in that the flame was not sufficiently reducing in character.

At this meeting sets of samples were given out to various members and visitors to be heat treated to get certain properties. These heat treated samples will be returned to the Stunt Night Committee at the February meeting. Tensile tests, etc., which cannot be conducted easily at a regular meeting, will be made on the specimens during the following month, and the results will be ready for publication at the Contest meeting in March. At this meeting it is proposed to test all the specimens by means of the scleroscope, Brinell test, and Rockwell test. The committee has promised to have a good supply of inspection files present, and the various ideas of "file hardness" of the different members will be compared. It is also hoped to have one of the new Stacks spark testers in operation. This meeting will not only serve as a competition between rival heat treaters, but will also serve to show the man at the fire how his product is being checked up in his own inspection department and by the consumer.

In order to lighten the serious aspect of this meeting, certain of the samples distributed bear no identifying marks, so that the person by whom they are received has no idea of the composition of the steel. The results obtained on these dark horses should provide a lot of fun. A box of cigars is offered as a prize to the competitor who receives the greatest number of points for his work.

The regular February meeting of the Hartford Chapter was held on Feb. 9, in Jewell Hall of the Hartford Y. M. C. A. The attendance at the meeting was about 120, of whom about 50 were members, the remainder guests. The speaker of the evening was A. H. d'Arcambal, of the Pratt & Whitney Co., Hartford, and his subject was "High Speed Steel." Mr. d'Arcmabal has spoken on the same subject at national conventions and before various chapters of the Society, and his talk on this occasion was an abstract of the material which he has presented heretofore in his various talks, with additional data developed in recent tests. Specimens of tools showing proper and improper treatment were exhibited, and the reasons for failure or success of each treatment were discussed. Specimens of the two common types of high speed steel, that is, 14 and 18 per cent tungsten steels, were shown with fractures after treatment and soaking at various temperatures.

From Mr. d'Arcambal's tests it appeared that the grain of the 14 per cent tungsten type coarsened more rapidly than the 18 per cent under the various treatments, in other words, it is a more sensitive steel, and must be handled more carefully. Cutting tests, however, showed that the lower tungsten steels stood up in service somewhat better than those containing 18 per cent tungsten. One interesting chart showed the Brinell, scleroscope, and file hardness of high speed steel quenched from various temperatures plotted simultaneously with the same properties for the same steel quenched at the same temperatures, but drawn back at 1100 degrees Fahr. It was observed that for quenching temperatures below 2300 degrees Fahr., the specimens

drawn at 1100 degrees were softer than the quenched and undrawn specimens. At 2300 degrees Fahr. and higher, the specimens retained their original hardness. This appears to vindicate the proponents of the higher quenching temperatures, that is, 2300 degrees Fahr. and higher, also the exponents of the high draw. Considerable discussion of the paper ensued, in which the desirability of carbon content in excess of 0.65 per cent was emphasized.

After Mr. d'Arcambal's paper, specimens heat treated by various members were collected to be surface ground and otherwise prepared for testing at the March meeting. This meeting will be a Heat Treatment Contest, and specimens prepared by the committee and heat treated by different members and guests will be tested by the various modern methods of inspection applied to heat treated products. It is anticipated that the tests will cause a great deal of fun, and it is probable that there will be some difficulty in awarding the prize. The contest committee, however, wish to have it known that they "are boss," and what they say, goes.

Mr. Curran described some recent work of W. R. Chapin, on the "Properties of Steel in the Hardening Range," or the range between Ac_1 and Ar_1 which has been lowered by quenching from above Ac_1. Test pieces were exhibited, which had been quenched from above the critical range but removed from the quenching bath in the range 800 to 1200 degrees Fahr. While at this temperature, the Rockwell hardness and file hardness were relatively low, and the specimens could be bent easily and otherwise deformed. When subsequently quenched into oil at about 300 degrees Fahr., however, the specimens were file hard, and showed a Rockwell hardness characteristic for the steel quenched cold in the usual way.

The list of meetings for the remainder of the season is as follows:

March 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.

April 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Matthews, President Crucible Steel Co., Pittsburgh.

April 29:—9:00 a. m., Inspection of New Departure Co. Plant Britol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.

May 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.

June 8:—Annual Banquet. Speakers to be announced later.

In additioon to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

NEW YORK CHAPTER

At the regular January meeting of the New York Chapter held in the Engineering Society's building on Wednesday evening, Jan. 18, some 80 members and guests assembled to hear a very excellent paper by A. W. F. Green, metallurgist, John Illingsworth Steel Co., Philadelphia. Mr. Green presented an illustrated lecture on "Annealing." He took particular care to impress upon his hearers the difference between "full annealing" and "partial annealing," the first accomplished at temperatures above the critical, and the second at temperatures just below the critical. He presented a number of lantern slides showing how the theory of the process was borne out by observation of the finished pieces, after undergoing treatment of both kinds. An animated discussion followed.

In a brief period devoted to current events in metallurgy mention was

made of the completed work on the fatigue of metal, and the discovery of a rapid method for determining the endurance limit; work which has been going on at the University of Illinois under the direction of Prof. H. F. Moore.

The regular February monthly meeting of the Chapter was held on Wednesday, Feb. 15, in the assembly room of the Merchants Association of New York. The room has been very generously tendered to the section for its regular use, and is conveniently situated in the Woolworth building. Located as it is at the focus of the rapid transit systems of the Metropolitan District, this meeting place seems to solve the question "Where can we meet where it will be convenient to our widely scattered mmbers?"

S. P. Rockwell prepared a paper on carbonizing practice, but unfortunately was unable to attend owing to sudden and serious illness in his family. Captain Walter C. Graham read his paper, and made it doubly interesting by a critical commentary on the subject, prompted by his own very thorough knowledge. About sixty members were in attendance.

Commercial Items of Interest

THE American Engineering Standards Committee has just completed arrangements by which co-operation with the standardizing bodies in other countries will be made more effective. In doing this, it has followed out the recommendations of the unofficial conference of the secretaries of the national standardizing bodies held in London in April, 1921.

In order that all standards shall be available to the industries of the various countries, it is planned that each national body will sell the approved standards of the other bodies. The American Engineering Standards Committee, 29 West Thirty-ninth street, New York, has available the publications of the standardizing bodies in Austria, Belgium, Canada, France, Germany, Great Britain, Holland, Sweden and Switzerland.

Hereafter the American Engineering Standards Committee will exchange regularly information with the foreign bodies as to the status of work on the various projects being undertaken under its auspices. This information will be limited to the indication of the stage of development of the projects, it being left in each case to the various sectional committees and sponsor bodies to decide to what extent they desire to exchange technical memoranda or drafts of standards. This exchange of information on the general progress of the work will lay the basis for closer international co-operation as the need for this develops in special instances.

Installation of 67 double frame drop hammers at the Highland Park plant of the Ford Motor Co., Detroit, now being effected, is the first important step by the Ford organization in its plan to do practically all of its own drop forging work under its own roof. At the present time, practically all of this work, which is enormous, is let out to numerous companies. These 67 hammers will bring the total hammer equipment of the Ford company to 100. The new hammers range from 800 to 5000 pounds and are being placed in operation immediately upon being set up. It is expected it will be several months before all are in operation.

Detroit has been selected as the meeting place of the National Safety Congress to be held Aug. 28 to Sept. 2, inclusive, under the auspices of the National Safety Council, Chicago. A local committee to handle the preliminary details relative to the meeting has been named with S. C. Mumford, president of the Detroit Safety Council, as chairman.

Announcement is made of a new edition of *Hendricks Commercial Register of the United States,* a 2324-page listing of business organizations published by the S. E. Hendricks Co., Inc. By way of review *The Iron Trade Review* says:

"The 1922 edition of this book differs from those of previous years in that the size has been changed in the interest of readability. The new

type size is 7 x 10 inches and more space has been allowed between lines and columns. In spite of the fact that the enlarged page accommodates 25 per cent more subject matter, the number of pages has not been decreased proportionately.

"As in former editions, the book covers a wide range of industries and lists the manufacturers of equipment under many headings, including electrical, engineering, machinery, building, manufacturing, chemical, hardware, iron and steel, railroads, mining, quarrying, architectural, etc. Dealers, manufacturers, producers, and consumers are registered. At least 100,000 names of individuals and companies are classified by trades or products, and are indexed and cross indexed. A separate section furnishes references to distinctive products, listed by trade names or special brands. In another section the names of manufacturers are arranged alphabetically and their addresses and principal products are given.

"Primarily the book is intended to be a guide for buyers and sellers and to this end the descriptive information of products and services is expected to assist in locating the sources of and outlets for finished materials."

Wilson-Maeulen Co., 383 Concord avenue, New York, announces that Carl E. Hellenberg, with headquarters at 231 California avenue, Detroit, has been appointed the company's representative for Michigan and northwestern Ohio. Mr. Hellenberg has had much practical experience in both hardness testing and pyrometry and he will take care of the company's interests regarding both its direct reading hardness testers and pyrometers.

Effective March 1, the St. Louis office of the Chicago Flexible Shaft Co., Chicago, manufacturers of flexible shaft machinery, and gas and oil furnaces, will be resumed. J. J. Wittenburg, who has been in the Chicago office of the company for three years, will be in charge. As previously, the St. Louis office will be located in the Railway Exchange building.

Joseph H. Roberts, superintendent of the bar steel and special products department, Nicetown works of the Midvale Steel & Ordnance Co., has resigned to accept the position of assistant to L. J. Campbell, president of the Electric Alloy Steel Co., Youngstown, O.

The American Society for Testing Materials, 1315 Spruce street, Philadelphia, has recently published its proceedings of the twenty-fourth annual meeting held at Asbury Park, N. J., June 21-24, 1921. It contains 1198 pages, 6 x 9 inches, and is bound in cloth. By way of review, *The Iron Trade Review* says:

"This volume of *Proceedings* contains committee reports, new and revised tentative standards, and technical papers presented at the last annual meeting of the American Society for Testing Materials. The meeting is briefly summarized in the first part of the book and the president's annual address and the report of the executive committee are given in full. The next section is devoted to reports of committees including those on ferrous metals; nonferrous metals; cement, lime, gypsum and clay products; and miscellaneous materials. Tentative standards submit-

TRANSACTIONS
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PROPOSES STANDARDS FOR CARBON AND ALLOY STEEL COMPOSITIONS

ATTENTION of members of the Society is directed to the communication and report of the Standards Committee on page 557 of this issue of TRANSACTIONS. After considerable time and effort this committee has prepared and submitted to the membership a proposed set of standards for the chemical compositions of both carbon and alloy steels. In a number of cases, the same standards as sanctioned by the Society for Automotive engineers are recommended, but in other cases some modifications have been found desirable. This committee now solicits criticisms and suggestions in order that any necessary changes may be made in sufficient time that definite recommendations for a set of standards may be made at the Detroit Convention, Oct. 2 to 7. All letters proposing changes must be in the hands of the committee by May 26 when it will hold its next meeting.

If the Society is to expect the Standards Committee to accomplish any notable work such as it has started at the present time, the chapters and membership must give it the greatest co-operation. A responsibility rests upon chapter officers to see that the proposed standard analyses are brought to the attention of the chapter at the next meeting where they may be discussed openly. Following this, a committee should be appointed to consider the proposed standards and to report to the National Office whether they are considered favorable or unfavorable. Individual members should send their suggestions in direct. Within recent years the matter of standards and standardization has received wide attention, and it is only in line with the general progress that this Society should adopt a suitable set of standards.

PROGRAM ANNOUNCED FOR PITTSBURGH SECTIONAL MEETING

W. J. MERTEN, chairman of the Papers and Meetings Committee of the Pittsburgh Chapter has issued an announcement giving the program for the Spring Meeting of the National Society at Pittsburgh, May 25 and 26. This committee as well as the various other committees on arrangements have accomplished excellent results and have everything in shape for a successful meeting.

Since the New York Meeting was such a decided success and attracted so many out-of-town guests, the Pittsburgh Chapter contemplates that the program and entertainment features as well as the exceptional opportunity afforded for plant visitation will combine in producing a large attendance from outside chapters.

The papers to be presented at the Pittsburgh meeting will be pub-

lished in the May issue of TRANSACTIONS which it is hoped will be in the hands of all members not later than the first of May. Discussion is invited on all the papers and it is hoped that many members will take the opportunity to comment upon the papers to be presented. The program is as follows:

PROGRAM FOR THE SPRING SECTIONAL MEETING AT PITTSBURGH, MAY 25 TO 27

Thursday, May 25

11 a. m. to 1 p. m.—Auditorium, Bureau of Mines.

Informal gathering and registration of out-of-town members and guests. In charge of W. H. Eisenman, National Secretary, assisted by Messrs. Horne, Phillips, and Cook.

1:30 p. m. to 4:30 p. m.—Auditorium, Bureau of Mines.

Address of welcome, by Chairman of Pittsburgh Chapter.
Response by National President, F. P. Gilligan.
Technical Session presided over by Past Chairman of Pittsburgh Chapter.
Papers by:

Professor McIntosh, Carnegie Institute of Technology, "Fiber in Steel and Iron".
W. B. Crowe, metallurgist, Carnegie Steel Company, "Mass Influence on Heat Treating".

7:00 p. m.—University Club—Banquet.

Addresses and music relayed over KDKA, Westinghouse Radiophone station.
Toastmaster—G. H. Neilson, president, Braeburn Steel Co. and past president, Western Pennsylvania Engineers Society.
Speakers—Doctor Bowman, chancellor, University of Pittsburgh; Dr. J. A. Mathews, president, Crucible Steel Co. of America; Prof. F. Crabtree, chairman, American Institute of Mining and Metallurgical Engineers, Pittsburgh Division; and vice chairman, Western Pennsylvania Engineers Society. "History of Metallography and Heat Treatment of Iron and Steel".
Followed by impromptu speeches by guests representing prominent local industries.
Music by Greater Pittsburgh Quartet.

Friday, May 26

9:00 a. m. to 12:00 m.

Assembly at Schenley Hotel to visit steel mills and manufacturing plants.

1:30 p. m. to 4:30 p. m.—Auditorium, Bureau of Mines.

Technical Session—Presided over by Chairman of visiting section.
Papers by:

Mr. Cox, R. D. Nuttall Co., "Abrasive Qualities of Carbon and Alloy Steels".
J. A. Succop, Heppenstall Forge & Knife Co., "The Importance of Properly Heated and Cooling Steel".
Mr. Smith, Union Spring & Manufacturing Co., New Kensington, Pa., "Manufacture of Springs".
Mr. Grossman, Electric Alloy Steel Co., Youngstown, O., "Shrinkage of High Speed Steels".

7:30 p. m. to 11:00 p. m.—Auditorium and Cafeteria, Bureau of Mines.

Open-Hearth Furnace Film—American Rolling Mill Company.
Smoker, in charge of Entertainment Committee.

Saturday, May 27

10.00 a. m.—Auditorium, Bureau of Mines.

Directors meeting.

8:00 p. m.

Carnegie Institute of Technology, School of Dramatic Arts. Little Theater play by School of Dramatic Arts.

HOTEL RESERVATIONS FOR DETROIT CONVENTION

Statler Hotel, Convention Headquarters

DETROIT has promised to provide all of our members and guests with excellent accommodations as far as hotels are concerned. Through the efforts of D. J. Crowley, 832 Dime Bank Building, Detroit, Chairman of the Hotel Committee, a list of hotels is given below with their rates for single and double rooms as well as the number of reservations each hotel will accept. The Statler Hotel will be the official headquarters. All persons in attendance at Detroit will make their own hotel reservation direct with the managers and it is advisable that the members take the following precaution: When making reservations, state that you are attending the International Steel Exposition and Convention of the American Society for Steel Treating, give the date of arrival, kind of room desired and the price you wish to pay. Request the hotel manager to answer your letter repeating the reservation, then take the letter with you to Detroit and present it when you register. This precaution taken now may avoid serious difficulty during the rush of the Convention. It is recommended that reservations be made immediately.

The list of hotels follow:

Lincoln Hotel

Rate Without Bath	Rate With Bath
Single $1.25, $1.50, $1.75, $2.00	Single 6 showers and tubs on each floor
Double $2.50, $3.00 (2 men)	Double no private baths

Will accommodate 75

Remarks: Large lobby. Good cafeteria.

Hotel Fort Shelby

Rate Without Bath	Rate With Bath
Single $2.00	Single $3.00, $3.50, $4.00, $5.00
Double $3.00	Double $5.00, $6.00, $7.00

Will accommodate 50 to 100

Cadillac Hotel

Rate Without Bath	Rate With Bath
Single 2.00, $2.50	Single $2.50, $3.00, $3.50, $4.00
Double $3.00, $3.50, $4.00	Double $4.00, $5.00, $6.00, $7.00

Will accommodate 500

Charlevoix Hotel

Rate With Bath	
Single $3.00, $3.50, $4.00	Two-Room Suites.....$7.00
Double $5.00, $6.00	Three-Room Suites $8.25
	Four-Room Suites $9.00

Number of persons with notice—100

Hotel Wolverine

Rate With Bath

Single $2.50, $3.00, $3.50, $4.00, $4.50, $5.00, $6.00

Double $4.50, $5.00, $5.50, $6.00, $6.50, $7.00, $8.00

Will accommodate 300

Hotel Norton

Rate Without Bath	Rate With Bath
Single $2.00 to $2.25	Single $2.50 to $3.00
Double $4.00	Double $4.50 to $5.50

Will accommodate 100

Hotel Normandie

Rate Without Bath	Rate With Bath
Single $1.50 to $2.00	Single $2.50 to $3.00
Double $2.50 to $3.00	Double $3.50 to $4.00

Will accommodate 100

Madison-Lenox

Rate Without Bath	Rate With Bath
Single $2.00	Single $2.50, $3.00
Double $3.00	Double $3.50, $4.00

Will accommodate 100 or more

Library Park Hotel

Rate Without Bath	Rate With Bath
Single $1.25 to $2.00	Single $3.00
Double $2.00 to $3.00	Double $4.00

Will accommodate 50

Hotel Stevenson

Rate With Bath
Single $2.50
Double $3.50
Will accommodate 50

Hotel Statler

Rate With Shower	Rate With Bath
Single $3.00 to $3.50	Single $4.00 to $ 8.00
Double $5.00 to $5.50	Double $6.00 to $10.00

Will accommodate—400 rooms to take care of 600 to 800 people

Hotel Tuller

Rate With Bath
Single $2.50
Double $4.50
Will accommodate 300

Hotel Griswold

Rate Without Bath	Rate With Bath
Single $2.00	Single $2.50, $3.00, $3.50
Double $3.00	Double $4.00, $5.00, $6.00

Will accommodate 125

Hotel Addison

Rate Without Bath	Rate With Bath
Single $1.50	Single $2.50
Double $3.00	Double $4.00

Will accommodate 250

ARRANGES TECHNOLOGIC PAPERS FOR REFERENCE

THE following announcement recently made by the Bureau of Standards, Washington, suggesting a standard method for collecting and binding technologic papers issued by the bureau periodically probably will be of interest to members of the American Society for Steel Treating. The announcement is as follows:

"The need for citation to the Technologic Papers of the Bureau of Standards has brought requests that they be grouped into volumes, each volume being consecutively paged. Most libraries do not usually index pamphlets, and as these Technologic Papers are classed as pamphlets, their reference value is lost. To combine the advantages of the separate reprint system and the volume plan will be so helpful that beginning with Technologic Paper No. 203 the paging will be consecutive in the series until 750 pages are reached. This will permit gathering together the Technologic Papers into volumes wherever desired.

"Since 202 papers are already issued, a suggested grouping for these

also is published herein to aid those who may have complete sets unbound. The volume is uniform in style and size with that of the Scientific Papers of the Bureau of Standards. Since so few copies are available for free distribution, it is no longer possible to complete all the sets from the beginning. The Superintendent of Documents maintains a sales stock which will help to complete back sets, and he reprints any publication for which there is sufficient demand.

"The suggested grouping of Technologic Papers into volumes need not be followed by libraries which classify the papers on the shelves by subjects, but the suggested grouping will be convenient for those libraries which maintain the series in consecutive order as sent out. The grouping suggested for binding in such cases is as follows:

Vol. No.	Begins with—	Vol. No.	Begins with—	Vol. No.	Begins with—	Vol. No.	Begins with —
1.....	T 1	5.....	T43	9.....	T 85	13.....	T143
2.....	T12	6.....	T54	10.....	T101	14.....	T170
3.....	T20	7.....	T61	11.....	T109	15.....	T184
4.....	T32	8.....	T74	12.....	T121	16.....	T203

"Cited references to earlier Technologic Papers, issued prior to No. 203 which begins volume 16, should be to the separate papers, that is, "Bureau of Standards Technologic Papers, No. 170, p. 92, 1921."

"A title page and index, issued separately, will be transmitted with the last Technologic Paper of each volume to those libraries or subscribers who receive the complete series.

"Subscriptions can be placed for the series of Technologic Papers by sending written orders addressed "Superintendent of Documents, Government Printing Office, Washington, D. C.," and inclosing $1.25 to cover a sufficient number of the papers to make one volume ($2.50 is required if the publications are to be mailed to foreign countries). Separate numbers of the Technologic Papers may be purchased at nominal cost by sending to the same address. Do not address orders with money to the Bureau of Standards or the Department of Commerce.

"Circular 24 contains a descriptive list of all Bureau of Standards publications issued since the establishment of the Bureau. An extended abstract shows clearly the nature of the subject matter and gives in many cases a brief summary of the result. This list will be distributed to applicants free of charge."

PREDICTS FUTURE FOR MAGNETIC TESTING

THE following editorial entitled "An Advance in Magnetic Testing" appeared in the March 9 issue of the *Iron Age* and is of timely interest. It was occasioned by the paper "The Magnetic Testing of Small Case Hardened Chain" which was presented by A. V. deForest at the New York Sectional meeting of the Society held on March 3. The editorial read as follows:

"Magnetic testing has now been applied for determining the efficacy of case hardening. More than that, it has been applied in a practical way that suggests broad possibilities. Announcement of the development was made at the meeting last week to discuss steel treating problems and covered the perfection of an apparatus used for testing the case hardness of small chain. Briefly, by empirically determining the maximum and mini-

mum depths of case in chain corresponding to poor results, an approximate standard is established by which it is possible to determine magnetically the depth of case which will give the longest life for definite conditions. This has already afforded a test basis which is being applied commercially.

"This principle may, in the not distant future, be applied to other properties of steel. The designers of the apparatus are making just such predictions and assert that it will be possible to correlate the tensile strength or ductility as easily by magnetic tests as the case hardness of steel. All that appears necessary is the determination of maximum and minimum limits within which the material will be satisfactory and use these for the fixing of a standard. There are those who do not appreciate that this is really the principle on which most specifications are now based. New apparatus will not be needed, it is claimed. The application of the magnetic testing idea to case hardened chain is after all merely a step in the development of nondestructive testing for which there has long been a demand."

A HISTORIC DESCRIPTION OF DAMASCUS SWORD MAKING

IN SYRIAC characters, in the ruins of ancient Tyre was found the method of making perfect Damascus sword blades. Translated the procedure was as follows:

"Let the high dignitary furnish an Ethiope of fair frame, and let him be bound down, shoulders upwards upon the block of the God Bal-hal, his arms fastened underneath with thongs; a strap of goatskin over his back, and wound twice around the block; his feet close together lashed to a dowel of wood, and his head and neck projecting over and beyond the block - - - Then let the master workman, having cold hammered the blade to a smooth and thin edge, thrust it into the fire of the cedarwood coals, in and out, the while reciting the prayer to the God Bal-hal, until the steel be of the color of the rising sun when he comes up over the desert toward the East and then with a quick motion pass the same from the heel thereof to the point, six times through the most fleshy part of the slave's back and thighs, when it shall have become the color of the purple of the king. Then if with one swing and one stroke of the right arm of the master workman it severs the head of the slave from his body, and display not nick nor crack along the edge, and the blade may be bent round about the body of a man and break not, it shall be accepted as a perfect weapon, sacred to the service of the God Bal-hal, and the owner thereof may thrust it into a scabbard of asses' skin, brazen with brass, and hung to a girdle of camels' wool dyed in royal purple."

STANDARDS COMMITTEE REPORTS ITS PROGRESS

BELOW will be found a communication from the Standards Committee of the American Society for Steel Treating which accompanied the proposed standards on the composition of steel. In preparing these standards the committee has done a considerable amount of work but has reached the point where criticisms and suggestions are desired. Another meeting will be held May 26 at which time all communications will be considered. The committee's letter is as follows:

"Subject: Composition of Steel—Standards.

"At a meeting of the Standards Committee in New York, March 2, 1922, a report was submitted by a subcommittee giving a proposed A. S. S. T. Analysis by the numbering system.

"The first list gives the key to the numbering system which it will be found corresponds to the S. A. E. plan but slightly extended to meet the more general needs of the A. S. S. T. Following that are given lists of steels that we wish to establish as standards, covering the plain carbon and alloy steels.

"The Committee voted that I, as chairman of the Committee, request the following co-operation:.

"Send copies to each chapter of A. S. S. T. and publish same in the TRANSACTIONS with a notation that:

1. There is a growing national demand for a numbering system for chemical analysis of steels.
2. There is a national need for standardizing chemical analysis of steels.
3. The numbering system of the S. A. E. has become well established.
4. The national standards committee of the A. S. S. T. has worked out the attached tentative list of chemical analysis of steel which they propose to offer to the Society at the next annual convention, to be held at Detroit, Oct. 2 to 7, as standards.

"It is desired that each and all chapters take up this subject as a chapter matter and let the Standards Committee have their comments, criticisms or additional analyses that the several chapters may desire to offer.

"Individual members of the A. S. S. T. are requested to study the proposed standards and send in their comments and criticisms.

"We desire to have another meeting of the Standards Committee in Pittsburgh on or about May 26, 1922, and would appreciate replies before that meeting.

"The earnest co-operation of all members is desired by the Standards Committee and we shall expect full criticisms from those who have something better to propose.

"This we think is part of the foundation of the Standards Committee's work in building up the National Society.

Yours truly,
STANDARDS COMMITTEE,
ROBERT BIRD,
J. H. G. WILLIAMS,
T. D. LYNCH, Chrm.

"Send all comments and criticisms to the National office, 4600 Prospect Avenue, Cleveland, O."

PROPOSED A. S. S. T. STANDARDS

Key to Numbering System

"GRADE" Designated by the 1st number:

- 10-00 Carbon
- 20-00 Nickel
- 30-00 Nickel Chromium
- 40-00 Molybdenum
- 50-00 Chromium
- 60-00 Chrome Vanadium
- 70-00 Tungsten
- 90-00 Silico Manganese

"TYPE" Designated by the 2nd number:

- 00-00, 01-00 General for Carbon Steels
  - 11-00 High Phosphorus and Sulphur
  - 12-00 Steel Casting
- 02-00, 03-00, 04-00, 05-00 Indicates content of Main Alloy
- 06-00 High Manganese
- 08-00 Close Limits—Physical Requirements

"CARBON CONTENT" Designated by last two numbers:

- 00-05 Average .05 Carbon
- 00-10 Average .10 Carbon
- Etc.

Illustrations

10-15	10-20	Carbon Simple Carbon	
10-36	30-40	Carbon Simple Carbon	
11-12	08-16	Carbon High Phosphorus and Sulphur	Case Hardening
25-35	30-40	Carbon 3.5 per cent Nickel	Forging Steel
32-30	25-35	Carbon Intermediate Nickel Chrome	Free Cutting
33-25	20-30	Carbon Full Nickel Chrome	

Carbon Steels

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Silicon	
10-00	-25	-50	05	-06		
10-10	05-15	30-60	045	05		SAE
10-15	10-20	30-60	045	05		SAE
10-20	15-25	30-60	045	05		SAE
10-21	10-30	20-80	05	06		
10-25	20-30	50-80	045	05		SAE
10-30	25-35	50-80	045	05		SAE
10-35	30-40	50-80	045	05		SAE
10-36	30-40	40-60	045	05		
10-40	35-45	50-80	045	05		SAE
10-41	35-45	40-60	045	05		
10-45	40-50	50-80	045	05		SAE
10-46	40-50	40-60	045	05		SAE
10-50	45-55	50-80	045	05		SAE
10-51	45-55	40-60	045	05		
10-55	50-60	40-60	045	05		
10-60	55-65	60-80	045	045		
10-65	60-70	50-70	04	045		
10-70	65-75	30-60	04	045		
10-75	70-80	20-50	04	045		
10-80	75-85	20-50	04	045		
10-85	80-90	20-50	04	045		
10-90	85-95	20-50	04	045		
10-94	90-1.00	20-50	04	045	15-25	
10-95	90-1.05	20-50	05	05		SAE
10-99	90-1.10	20-50	05	05		

High Phosphorus and Sulphur Steels

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	
11-12	08-16	60-80	09-13	075-.15		SAE
11-20	15-25	60-90	06	075-.15		SAE

Nickel Steels

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	
21-30	27-33	40-60	04	04	1.00/1.25	
23-12	18	30-60	04	045	3.25/3.75	SAE
23-15	10-20	30-60	04	045	3.25/3.75	SAE
23-20	15-25	50-80	04	045	3.25/3.75	SAE
23-30	25-35	50-80	04	045	3.25/3.75	SAE
23-35	30-40	50-80	04	045	3.25/3.75	SAE
23-40	35-45	50-80	04	045	3.25-3.75	SAE
23-45	40-50	50-80	04	045	3.25/3.75	SAE
23-50	45-55	50-80	04	045	3.25/3.75	SAE
25-12	17	30-60	04	045	4.50/5.25	SAE

Nickel Chrome—Mayariz

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	
31-12	.18	30-60	.04	.04	1.00/1.50	45-75	
31-15	10-20	30-60	.04	.04	1.00/1.50	45-75	SAE
31-20	15-25	30-60	.04	.045	1.00/1.50	45-75	SAE
31-25	20-30	50-80	.04	.045	1.00/1.50	45-75	SAE
31-30	25-35	50-80	.04	.045	1.00/1.50	45-75	SAE
31-35	30-40	50-80	.04	.045	1.00/1.50	45-75	SAE
31-40	35-45	50-80	.04	.045	1.00/1.50	45-75	SAE
31-45	40-50	50-80	.04	.045	1.00/1.50	45-75	
31-50	45-55	50-80	.04	.045	1.00/1.50	45-75	

Nickel Chrome—Intermediate

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	
32-12	17	30-60	.04	.04	1.50/2.00	90/1.25	
32-15	10-20	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-20	15-25	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-25	20-30	30-60	.04	0.45	1.50/2.00	90/1.25	
32-30	25-35	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-35	30-40	30-60	.04	.045	1.50/2.00	90/1.25	
32-40	35-45	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-45	40-50	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-50	45-55	30-60	.04	.04	1.50/2.00	90/1.25	SAE
32-55	50-60	30-60	.04	.045	1.50/2.00	90/1.25	SAE

Nickel Chrome—Full

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	
33-10	15	30-60	.04	.04	3.25/3.75	1.25/1.75	
33-12	17	30-60	.04	.04	3.25/3.75	1.25/1.75	SAE
33-19	15-25	30-60	.04	.045	3.00/3.50	1.00/1.50	
33-25	20-30	30-60	.04	.04	3.25/3.75	1.25/1.75	SAE
33-29	25-35	30-60	.04	.045	3.00/3.50	1.00/1.50	
33-34	30-40	30-60	.04	.045	3.00/3.50	1.00/1.50	
33-35	30-40	30-60	.04	.04	3.25/3.75	1.25/1.75	SAE
33-39	35-45	30-60	.04	.045	3.00/3.50	1.00/1.50	
33-40	35-45	30-60	.04	.04	3.25/3.75	1.25/1.75	SAE

Nickel Chrome—"French"

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	
34-12	18	30-60	.04	.04	2.75/3.25	60-95	
34-15	10-20	45-75	.04	.04	2.75/3.25	60-95	SAE
34-35	30-40	45-75	.04	.04	2.75/3.25	60-95	SAE
34-50	45-55	45-75	.04	.04	2.75-3.25	60-95	SAE

Chrome Steels

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Nickel	Chromium	
51-20	15-25	30-60	.04	.045		60-90	SAE
51-40	35-45	50-80	.04	.045		80/1.10	SAE
51-50	45-55	50-80	.04	.045		80/1.10	SAE
51-65	60-70	25-50	.04	.045		60-90	
52-100	95/1.10	20-50	.03	.03		1.20/1.50	SAE

Chrome Vanadium

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Chromium	
61-20	15-25	50-80	.04	.04	80/1.10	SAE
61-25	20-30	50-80	.04	.04	80/1.10	SAE
61-30	25-35	50-80	.04	.04	80/1.10	SAE
61-35	30-40	50-80	.04	.04	80/1.10	SAE
61-40	35-45	50-80	.04	.04	80/1.10	SAE
61-45	40-50	50-80	.04	.04	80/1.10	SAE
61-50	45-55	50-80	.04	.04	80/1.10	SAE
61-95	90/1.05	20-45	.03	.03	80/1.10	SAE

Silico Manganese Steel

Analysis No.	Carbon	Manganese	Phosphorus	Sulphur	Silicon	
92-50	45-55	60-90	.045	.045	1.80/2.20	SAE
92-60	55-65	60-90	.045	.045	1.80/2.20	SAE

STAINLESS STEELS AND THE MAKING OF CUTLERY

By R. G. Hall

COMMERCIAL utilization of the noncorrodible properties of steel containing about 13 per cent of chromium may be regarded as one of the outstanding events in the metallurgical world during the last decade. Unfortunately, steel, the most widely used metal, corrodes rather easily and great precautions have to be taken to protect it, especially in exposed positions. This is particularly noticeable in large engineering structures such as the great railway bridges where painting is going on practically continuously. The production of a type of steel possessing great resistance to corrosion obviously has a great future and one may safely say that as yet only the fringe of its possibilities has been touched.

Stainless steel, on account of its peculiar property of resisting oxidation and corrosion by the ordinary agents when properly hardened and finished was in great demand during the late war. Nearly all stainless supplies in England were appropriated by the minister of munitions, thus showing its importance during this stress period. The bulk of this material was used for exhaust valves in aero engines, on account of its strength and resistance to corrosion at high temperatures thus its use for cutlery was retarded.

The discovery of this steel was very unique because of the fact that two men working entirely independent of one another discovered the alloy at practically the same time. In 1911, Elwood Haynes, Kokomo, Ind., made experiments with alloys of iron and chromium with a view to determining the effects of chromium on the resistance of steel to chemical and atmospheric influences, also its effect on the hardness and cutting qualities of steel.

At about the same time or possibly a little later, Harry Brearley, a noted metallurgist of Sheffield, England, discovered that the introduction of approximately 13 per cent chromium to ordinary carbon steel, rendered it impervious to oxidation by air, water, or such acids that are usually met with in household use. The application of this steel to cutlery was made possible only after much experimenting and study by the various manufacturers of this particular line of goods.

The author has read a great mass of information compiled by several engineers as to the general characteristics of stainless steel for cutlery but he will not attempt to extract their points upon this particular steel for cutlery. Instead he will give the information as it has been worked out successfully at the fire and wheel. The writer has found great difficulty in studying the information as submitted by different authorities as there seems to be a great divergence of opinion as to practically all essential points, including the exact chemical specifications. A wide range of opinion exists as to the subsequent handling and heat treating of the alloy.

In enumerating these experiments, no attempt will be made to segregate them under separate headings but they will be given in abstract form. As to the analysis of the steel for cutlery, it is recommended that the carbon content be between 0.30 and 0.45 per cent and the chromium between 13 and 15 per cent. Doctor Hatfield recommends 13 per cent.

A paper presented at the New York Sectional Meeting. The author, R. G. Hall, is research engineer, R. Wallace & Sons Mfg. Co., Wallingford, Conn.

The Brearley patents call for chromium between 9 and 16 per cent while Elwood Haynes has covered in his patents up to 16 per cent. It is the opinion of the writer and others, however, that nothing is gained in stainless characteristics or corrosion by exceeding 15 per cent chromium. Phosphorus and sulphur should be below 0.03 per cent with silicon and manganese about 0.30 and 0.50 per cent respectively.

The steel generally used for cutlery is bought in round rods in convenient length to handle according to methods used in its manufacture. Some cutlery manufacturers work this steel from the bar, while others fabricate it to the desired lengths. The writer prefers the latter method because of its convenience and economy in scrap. Great care should be used in this method with reference to the tools used in fabrication because the cutlery troubles begin at this point. The steel always should be kept well annealed and if the tools are kept sharp, there should be no difficulty in cutting the material to the desired lengths. Dull tools at this point have a tendency to tear off the steel whereby small cracks are started in the end of some of the pieces and this generally leads to seamy portions in the blades. Steel manufacturers often are blamed for seamy stock when in reality the trouble has been due to dull tools. It might be stated here that in the early stages of this steel for cutlery, great difficulty was experienced at the mills in manufacturing this steel free from seams but today this trouble has been reduced to a minimum.

After the steel is cut into the desired lengths, it is taken to the drop forging room where it is forged into the desired shape. From here it passes on to the rolls where the blade is rolled out. Great care must be taken in these operations to maintain the heat at its proper forging temperature, especially at the roll, because at this point a part of the blade is nearly at its desired thickness while the remainder of the piece is still in its original round shape. The heat generally used at these stages of the manufacture range from 1650 to 1750 degrees Fahr.

The work must be kept as free as possible from oxidation because any scale rolled into the steel at this time may form a seat of corrosion even after the blade has been finished. When working with small thin sections, the alloy should never be allowed to cool on a damp cold floor on account of the air hardening qualities of this steel. Strains will be set up which later will develop into cracks, thus rendering the blade useless.

The next step in the manufacture is the annealing operation. The work is usually put into a receptacle and brought slowly up to about 1380 to 1400 degrees Fahr., generally in a muffle furnace, after which it is allowed to cool slowly. Following this operation the blades are blanked out into the desired shapes. Great care should be used at this point to see that the tools are kept sharp at all times, thus reducing the possibilities of cracks. These cracks caused by dull tools are not seen at this particular point and sometimes do not show up until considerable more labor has been expended.

The next step in the manufacture is the hardening operation, and this is one of the most difficult operations in the making of the whole knife. The hardening and tempering of stainless steel has much to do with its stainless characteristics, thus great care must be exercised. Stainless steel may be hardened in air, oil, or water, the quenching temperature really depending upon the method used. In the author's opinion, it should always be done in oil from a temperature ranging between 1650 to 1900

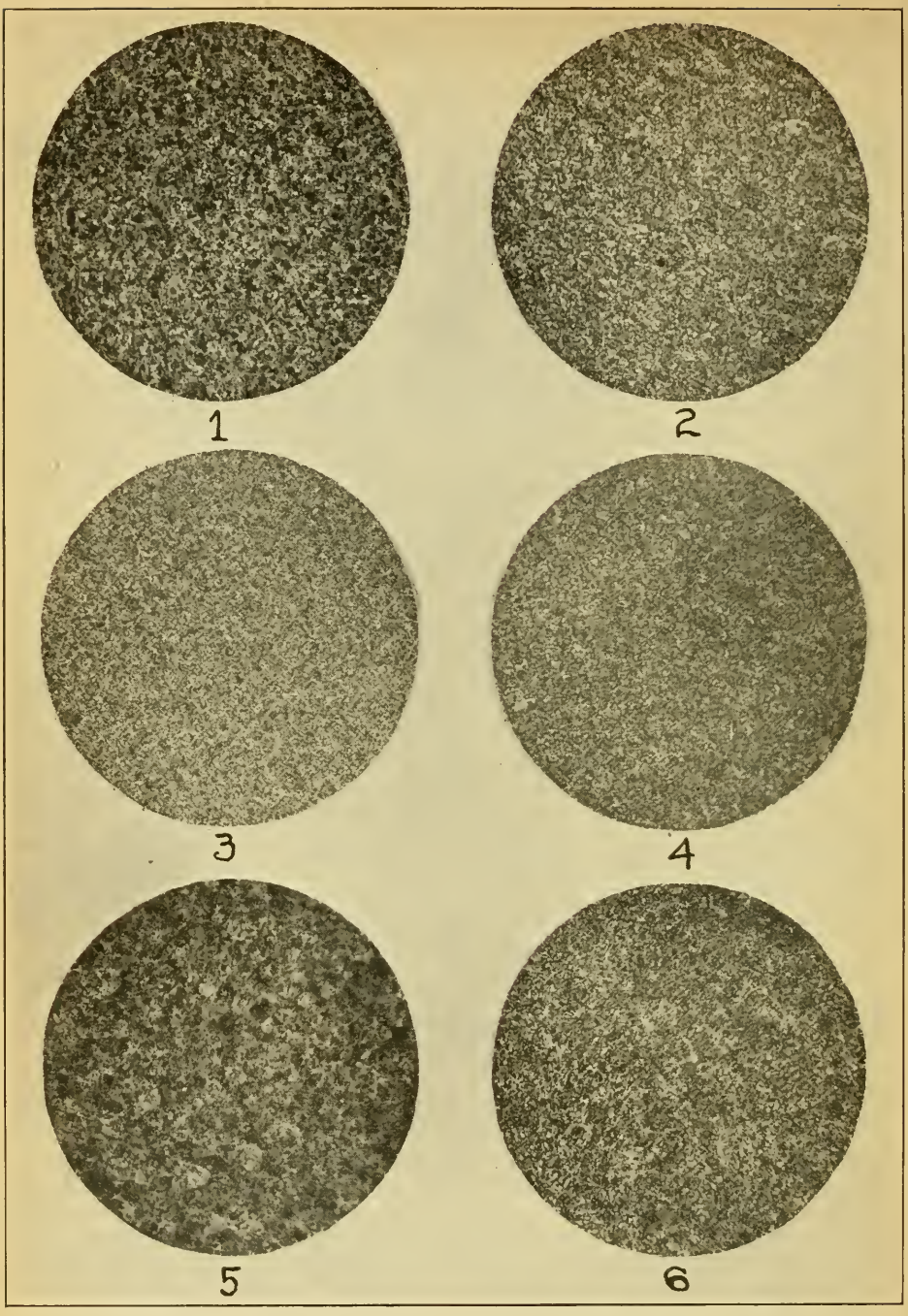
degrees Fahr., depending upon the carbon and chromium content of the steel.

Four knife blades were quenched in oil and four quenched in water to determine the difference in structure for stainless steel quenched in oil and water from temperatures of 1900, 1800, 1650 and 1600 degrees Fahr. On mounting, polishing, etching and examining at magnifications up to 500 diameters, no difference could be observed between specimens quenched in oil and in water from the same temperatures. Therefore only one micrograph is shown as characteristic for each of the four temperatures and these are represented by Figs. 1 to 4. Fig. 1 was quenched at 1900 degrees Fahr., Fig. 2 at 1800 degrees Fahr., Fig. 3 at 1650 degrees Fahr., and Fig. 4 at 1600 degrees Fahr. They are transverse sections etched in $FeCl_3$ acid and magnified 100 diameters. These specimens show the structures produced by quenching thin sections of stainless steel in either oil or water from the temperatures noted. The structures are all martensitic, although they lack the acicular form usually observed in quenched carbon steels and alloy steels of low alloy content. The grain size increases rapidly from the 1800 degree Fahr. to the 1900 degree Fahr. quenching temperature. The solution of the double carbide of iron and chromium is not complete at any of these temperatures, but is most complete after the 1900 degree Fahr. quench.

Figs. 5 and 6 show the structures of transverse sections observed at a magnification of 250 diameters in the blades quenched either in oil or water from 1900 and 1600 degrees Fahr. respectively. They were etched in $FeCl_3$ acid. The absence of the true acicular martensitic structure is evident in both plates. The only noticeable difference between the structures in these two figures is the larger grain size and more complete solution of carbides in the specimen quenched from the higher temperature.

Most low carbon steels in a hardened and undrawn condition show the elastic limit to be low and rather indefinite. It is only after drawing that a definite elasticity is established. Tests have shown that the elastic limits in stainless steel increase for a time with the drawing temperature and then begin to fall off like any other steel as the drawing temperature increases. Time limit enters into this phenomenon to a very large extent. A properly hardened blade must be drawn long enough to relieve the internal strains and this change must not be too rapid. The tempering colors appear in stainless steel at about twice the temperature of ordinary steel and are not altogether reliable. The writer is firmly convinced that the temper should be drawn to a definite temperature in a salt bath or an electric furnace.

The blades thus hardened and tempered are next taken to the grinding machines to be ground to the desired thickness and then tapered properly. Great care should be taken not to force this operation on account of the steel being unusually fine grained, and therefore very susceptible to that characteristic which the cutters call the grinders scorch. This particular kind of scorch polishes off easily but at the same time renders the steel directly under the scorch susceptible to stain. This characteristic must be avoided at all times. If any oxidation has taken place during previous operations, precaution should be taken at this point to see that it is thoroughly ground out for as has been said before any scale, no matter how small, will form a seat of corrosion which will invariably pass the inspectors and seldom show up until after the knives have been in use for a period of time. Following the grinding operation, the blades



Figs. 1-4—Transverse sections of stainless steel knife blades quenched from various temperatures in either oil or water. Etched in Fe Cl_3 acid and X 100. Fig. 1—Quenched at 1900 degrees Fahr. Fig. 2—Quenched at 1800 degrees Fahr. Fig. 3—Quenched at 1650 degrees Fahr. Fig. 4—Quenched at 1600 degrees Fahr. Figs. 5 and 6—Transverse sections of stainless steel knife blades quenched in either oil or water at 1900 and 1600 degrees Fahr. respectively. Etched in Fe Cl_3 acid and X 250. The only noticeable difference between structures is larger grain size and more complete solution of carbides in specimen quenched from higher temperature

are tested for temper, or in other words, they must stand an elastic limit of 1 to 5 inches. Stainless steel to be used for cutlery and to be in the most perfect condition should show a Brinell hardness between 525 and 550.

After the tempering test, the blades are glazed to remove all coarse grinding marks and this operation while simple requires an extra amount of work with a different grade of emery from that required for ordinary carbon steel. The knives are next taken to the inspection room where they are inspected to see if the glazers have removed all coarse grinding marks. The blades are then sent to the finishing room where the blades are mounted in handles. Here the backs, rims, points, bolsters, and necks are finished. The blade is then given the final glaze, and any other finishing touches needed to make it a first class knife.

The knife then goes to be tested for stainless qualities and if the blade is found to stain or copper plate after a two minute test with a concentrated solution of copper sulphate, the knife is rejected. After passing this test, the knives are etched and passed to the stock room ready for shipment. While there are some 40 operations through which these blades pass during their manufacture, only the high spots have been touched but they will give some idea of how this latest development in cutlery is manufactured.

In summarizing, it will be seen that the manufacture of a stainless steel blade, while not materially different in shape or size from that of an ordinary carbon steel blade. But the wear and tear on tools, furnaces, fires, extra operations, and rejections together with the extra price of stainless steel, which is seven or eight times the price of good carbon steel, makes the blade a very costly article.

It is interesting to know the test results of some of the different stainless steels that have found their way into the market. The writer has endeavored to take steels with wide difference in their chemical composition as to the two principal elements, namely, carbon and chromium. These samples were all forged at about 1700 degrees Fahr., and were hardened at different quenching heats according to their analysis, the quenching ranging from 1500 to 1900 degrees Fahr. These samples were all confirmed by three tests made up of concentrated solutions of acetic, tartaric and hydrochloric acids. The tests are as follows:

Steel No.	Carbon per cent	Chromium per cent	Stained in minutes	Cutting Efficiency
1	0.30	11.93	28	Satisfactory
2	0.20	12.21	35	Fair
3	0.40	12.60	13	Satisfactory
4	0.31	15.90	75	Satisfactory
5	1.10	23.32	43	Very good

Etching reagents used in grading stainless steel are: 1. Copper sulphate consisting of 4 grams of copper sulphate, 18 grams of sulphuric acid, and 90 grams of water; 2. Ordinary writing ink; and 3. Nitric acid having a specific gravity of 1.20. The time required for copper sulphate is 6 minutes, for writing ink 3 minutes and for nitric acid 2 minutes.

Discussion of Hall's Paper

MR. R. A. REIMAN: Do you have any trouble in the dies standing up in the trimming operations?

MR. HALL: No trouble, if the steel is well annealed.

MR. REIMAN: How about in the case of the 1.10 per cent carbon steel?

MR. HALL: The 1.10 per cent carbon steel is almost impossible to anneal, unless it is done hot.

MR. REIMAN: You do find difficulty in trimming in the case of the 1.10 per cent carbon steel?

MR. HALL: We have never been able to trim satisfactorily with 1.10 per cent carbon steel until we did it hot.

MR. REIMAN: What is the difference in the steel as compared with carbon steels so far as glazing is concerned?

MR. HALL: We have to give it an extra glazing. If you start in with the fine grain, you will find you are burning the surface and in burning the surface of the grain of steel it is very susceptible to stain.

MR. REIMAN: As compared to the carbon steel, how many operations do you make?

MR. HALL: Three.

MR. A. W. F. GREEN: Sometime ago I had the experience of going into a cutlery factory using both chromium for the stainless steels and the straight carbon steels. They found that they could not put the so-called "crocus" finish on the chromium steels. Can you tell me why that is so? By "crocus" finish, I mean the finish they put on by means of beeswax and glue on the wheel, mixed with red oxide.

MR. HALL: I don't think that is true; I think it can be done, although it is very difficult. If you file it down with the finest grade of emery which you can possibly get and get a fine bottom on it, it can be coated, although it is very difficult.

MR. GREEN: Do you know why it is so difficult?

MR. HALL: No, I don't except that the steel is so very fine grained and the color is hard to bring out.

MR. GREEN: Why does the steel with the larger grains, that is, quenched from 1900 degrees Fahr., when you have more or less of a large grain, so to speak, show a greater efficiency than one quenched at a lower temperature with greater grain refinement?

MR. HALL: The one that had the largest grain structures, Fig. 1 is not as good as the one under it, the one at 1800 degrees Fahr. as shown in Fig. 2. The one quenched at 1650 degrees Fahr. as shown in Fig. 3 will set. The 1800 degree Fahr. specimen did not set. You have to get them so that you can't set your blade, and in order not to set your blade you have to get your heat into it to make it a spring temper. I don't know why that is so, but I know it is so from practical knowledge; that is all I do know.

MR. REIMAN: What combination of steel, that is, as to carbon and chromium, do you find polishes best; or is there no difference?

MR. HALL: There isn't a great deal of difference; most of them polish about the same; they all polish high.

MR. A. L. DAVIS: Mr. Hall, what troubles do you have in hardening from a temperature such as 1800 degrees Fahr., which must render the blade

very soft, very pliable, and liable to be deformed; also, how about scaling?

MR. HALL: Stainless steel is very hard to scale anyhow. You can run that up into pretty high heat without making any perceptible scale on it. Keeping it in straight form is mostly in the tongs and the appliances that you use in the fire; they must not hit anything, and of course if they do they will bend.

MR. H. C. GOODWILL: Have you made any determinations up to date as to the ratio of stainless quality before and after heat treatment of stainless steel? In other words, stainless steel is, according to my understanding, presumably inherently stainless to a certain extent because of its composition. Have you any figures at all indicating whether or not that is so, and if so, what proportion of stainless quality it has as compared with the maximum after heat treatment?

MR. HALL: No, I have no figures. We have made tests along that line and have found that by polishing the steel it will stand quite a good deal of oxidation. I mean by that, it won't stain in any reasonable length of time. It will stain in time; but you will find much better results after it has been hardened.

MR. GOODWILL: What, to your mind, would be the stainless quality of the steel that had a content of about 0.10 per cent carbon, with the ordinary chrome commercial content?

MR. HALL: I don't know anything about it; we never tried any of it as low as that.

MR. A. E. BARKER: Can you tell me the Brinell hardness of those various steels at various temperatures?

MR. HALL: We have tested it, but I couldn't tell you offhand.

MR. BARKER: You couldn't tell whether the carbon steel quenched at 1900 degrees Fahr. gave a higher rating than that quenched at 1800 degrees Fahr.?

MR. HALL: The 1800 degrees Fahr. quench gave the highest rating.

MR. A. H. d'ARCAMBAL: What temperature do you draw your knives to?

MR. HALL: To about 650 degrees Fahr., for about 5 minutes.

MR. d'ARCAMBAL: Have you ever experimented with about a 0.60 per cent carbon, 0.40 per cent chromium steel?

MR. HALL: It will stain. You will find big blotches of stain on it. We used a copper sulphate test. Of course, everybody knows that you don't eat anything as strong as that, but we use is simply for a quick test, and we find that if it will stand two minutes of that, it will stand almost anything that goes on the table. We test every blade that goes out.

MR. D. S. WOLCOTT: I would like to know whether the results that you obtained from the forged blade would be verified if you tried out the double bevel blade? Have you experimented with both of them and tried the comparative merits of the two?

MR. HALL: You won't find any material difference if it is forged properly. You have to keep your heat up in forging; if you don't, you will get cracks. We use both.

MR. WHEELER: Has there been any effort to make carving forks, for instance, with stainless steel? Has that been successful?

MR. HALL: Yes, sir, they can be made very successfully and you can produce a very nice fork.

MR. REIMAN: Have you had any experience in making table cutlery out of rolled stock, sheet stock, not forged—the old method of making the table cutlery with the shape?

MR. HALL: Nothing, only in double bevel stock.

MR. HERBERT: You stated that you put the handle and the blade together after rough grinding, did you not?

MR. HALL: No, we glaze them twice before.

MR. HERBERT: What is the method of putting the handle and blade together, a soldering or welding process?

MR. HALL: Soldering in most cases.

MR. HERBERT: Have you had experience in welding this to a softer metal?

MR. HALL: You will find some difficulties, but it can be done.

MR. A. V. DeFOREST: Have any of these stainless steels better cutting quality than the ordinary carbon steels, and how is the cutting quality measured?

MR. HALL: I can't say that they are better, but they are fully as good. There are some that are not as good as carbon steel, but I think as a whole you will find that they are as good. I wouldn't say that they are any better.

MR. DeFOREST: How is the cutting quality measured?

MR. HALL: We test it out on cutting of a wooden stick, and we test it with a lathe and see how many shavings we can take off with one knife and then the other, before you have to hone it, or in other words sharpen it.

DISCUSSIONS OF PAPERS PRESENTED AT THE NEW YORK SECTIONAL MEETING

FOLLOWING are five of the stenographic reports of the discussions which were held after the presentation of technical papers read at the New York Sectional meeting, held in New York, March 3. The discussion of the paper "Stainless Steel in Cutlery Use" by R. G. Hall follows the paper published on page 561 of this issue of TRANSACTIONS.

Discussion of G. R. Brophy's Paper

This paper entitled "Calite—A New Heat Resisting Alloy" appeared on page 384 of the February issue of TRANSACTIONS.

MR. G. R. BROPHY: Calite is an alloy composed of iron, nickel, a small amount of chromium and aluminum, and depends upon its aluminum content for its heat resisting properties. It was brought out first purposely for carburizing boxes and containers, various heat treating containers, but numerous special applications have developed since, among these being its application in the manufacture of glass. It is probably the only alloy which can be used in the glass industry, that will not destroy the glass. There are also various chemical applications. The average operating temperature is about 1200 degrees Cent., however, it has been used at 1400 degrees Cent. without excessive oxidation—that was for a porcelain kiln.

Briefly, the physical properties of this alloy are:

Melting point, degrees Fahr.	2777
Softening temperature, degrees Fahr.	2500
Working temperature, degrees Fahr.	2200—2370
Specific gravity	7.03
Weight per cubic inch, pounds	0.25
Brinell hardness, annealed	286
Scleroscope hardness, annealed	40
Thermal conductivity, per cent of pure iron	25
Transverse stress, 1-inch square bar, pounds per square inch	4250
Tensile stress, pounds per square inch	36,800
Coefficient of thermal expansion, 20—300 degrees Cent.	.0000157
Coefficient of thermal expansion, 300—600 degrees Cent.	.000014
Coefficient of thermal expansion, 600—900 degrees Cent.	.0000192

We were asked to determine the coefficient of friction on ground surfaces, the grinding marks running at right angle, of two pieces at room temperature. It was 0.189 at room temperature, 1.450 at 550 degrees Cent., and 0.714 at 700 degrees Cent. Then after running at about 700 or 800 degrees Cent. and measuring again at room temperature, the coefficient was increased to 0.352. Cast iron under the same conditions has about the same coefficient of friction as 0.352. The specific heat of calite is 0.120, of pure iron 0.110, and of steel 0.12, calite being the same as steel. We believe that the specific heat is of more importance in the ordinary container retort than the conductivity. The conductivity is low, it is true.

We have made various chemical tests on this alloy. We find it very resistant to atmospheric corrosion in the polished condition. Samples have been polished and exposed to the conditions of the salt spray test at 100 degrees Fahr. and after 200 hours there was absolutely no attack, the calite retaining its mirror polish. Iron oxide, under 1000 degrees Fahr. has no attack on calite; over 1000 degrees Fahr. the calite is attacked. Silicious slags attack calite. Most molten salts that we have tried out have practically no attack on calite.

Sulphuric acid of 25 per cent strength dissolves calite rapidly; hydrochloric very slowly and nitric hardly at all. After 48 hours in 25 per cent nitric acid, the metal lost 0.0004 grams per square centimeter exposed. Acetic acid has no effect. Molten carbonates, chlorides, nitrates, cyanides, lead, zinc, tin and type metal, sulphur and sulphur vapor do not attack calite. Exposed to SO_2 gas and steam, the first 24 hours there was an increase of about 0.11 grams. After 106 hours there was no appreciable increase in weight. Other non-corroding metals which were tested for the same length of time showed a gradual decrease in weight.

MR. G. L. NORRIS: Is calite supplied only in cast form?

MR. BROPHY: Yes, at present.

MR. NORRIS: What are the possibilities of it being developed for rolled, drawn and other shapes?

MR. BROPHY: We have experiments under way now, and there is a good possibility of their being successful. On the other hand, up to a short time ago it would have been practically impossible for us to work this material. It is machined only with great difficulty. It can be done, however. We can do it, but it is not a good commercial proposition.

MR. ARTHUR F. BRAID: Can you give us the analysis of that material, Mr. Brophy?

MR. BROPHY: It is composed of nickel, iron, chromium and aluminum.

MR. JOHN J. CROWE: Mr. Brophy, have you any figures on the physical properties of the material at higher temperatures?

MR. BROPHY: We have not as yet; we expect, however, to have them shortly and we will try to publish them.

MR. J. E. HALBING: Have you encountered any difficulties in making thoroughly homogeneous castings in fairly large liquid containers with comparatively thin sections?

MR. BROPHY: It depends entirely upon the size of the castings. We have successfully cast sections down to 3/16-inch thick; that is about the minimum. I don't know but what we have gone thinner than that. Yes, we have cast sections ⅛-inch thick, pyrometer tubes, which, as we all know, is not an easy thing to cast. As far as the uniformity of the material is concerned, we have had no complaints on that score so far. With good foundry practice we have no particular trouble, but it is a new alloy and our method of molding must be changed to fit the alloy. Many difficulties must be worked out even yet.

MR. E. L. MALONE: So far as oxidizing properties are concerned, how does calite compare with the other alloys on the market, for lead pot work, for case hardening work?

MR. BROPHY: Molten lead has no attack. We have run calite containing molten lead for 100 to 150 or 200 hours, or something of that sort, and have had no failures. For case hardening work we have had no particular failures, although some case hardening compounds show some attack, usually in the form of a green salt. I don't know how serious that is. The tests were not conducted perhaps a sufficient length of time to show its life under those conditions.

MR. HALBING: What is the longest life that you have obtained so far with calite?

MR. BROPHY: We have had few failures.

MR. HALBING: How long have you run your containers?

MR. BROPHY: Mr. Farr, can you answer that question?

MR. A. V. FARR: Between 1500 and 2000 heat hours so far, that is, on carburizing boxes.

MR. BROPHY: We have, for our own use, run carburizing annealing boxes for 1500 hours and they are perfectly good after that. We discontinued the test and put them in service and they are still standing up after about 18 months use. In smaller carbonizing boxes, using bone as a carbonizing material, they have been in service for 18 months without failure.

MR. WIZENAK: What kind of fuel do you use in connection with these tests just mentioned?

MR. BROPHY: These tests were conducted in oil-fired furnaces. In the annealing test I speak of, these boxes (see illustration on page 385 February TRANSACTIONS were supported on a container for annealing electrical sheets. It was an over-fired furnace, and those boxes shown are acting actually as baffles; the flame is striking right against the box itself. I am sure if there was any attack, it would be shown up there.

MR. WIZENAK: Is it a low sulphur content oil or a high sulphur content oil?

MR. BROPHY: That I don't know.

MR. A. L. DAVIS: What trouble do you have with warping or distortion?

MR. BROPHY: Absolutely none. After 1500 hours we have actually micrometered the boxes and found very little change except what will take place, of course, in building the oxide.

MR. DAVIS: No growth in size?

MR. BROPHY: No growth. In regard to that question of sulphur in the fuel, I doubt very much if high sulphur would have any effect on it, because we have heated this material in superheated sulphur vapor and while it was attacked, it formed a protective coating.

MR. WIZENAK: The reason for asking is that we have had some samples and we have used that at carburizing temperature with a high sulphur oil and it has not shown us any favorable results so far.

MR. BROPHY: I would like to know more about your conditions. I say we have had few failures; we have in one or two instances put out samples that have failed. Now, truthfully, that failure has been mysterious; we don't know why, but I am sure the temperature on oxidation had nothing to do with it. I am sure I don't know why these failures occurred.

MR. WIZENAK: As a word of explanation, it is only a small sample and I don't want to make that statement as anything against the alloy, because it is only based upon a small sample.

MR. BROPHY: I think possibly I can explain some of that. The first heats of this metal were made with a certain mold facing which we found afterward to have rather a bad effect on the material. Since then our mold wash has been changed and I think perhaps new samples obtained would show better results.

MR. ESTABROOK: I would like to ask, in your bending tests, regarding the tensile strength under heat conditions, particularly at the high temperatures, say, 1500 degrees Fahr.?

MR. BROPHY: Those tests are under way and are about to be made.

MR. MALONE: Do the boxes stand up under the salt spray test at high temperatures?

MR. BROPHY: They polished very well.

MR. A. H. d'ARCAMBAL: How would calite do for an electric furnace, where you want to hold a small tool?

MR. BROPHY: It could be used for that purpose, but I don't believe you think that that is a good service. I wouldn't say that it would stand it, although in working out the first experiments on this alloy we used that as a test. The alloy that would stand quenching in the neighborhood of 1200 degrees Cent. was the alloy that we chose. For a complicated section, I would dislike to quench it.

MR. d'ARCAMBAL: We will try one.

MR. WALTER AURAND: There is one point that you haven't mentioned, which is rather an important one in some of these high alloys, that is, the tendency of this casting to crack after it stands 3 or 4 hours in the box. Have you had any difficulty along that line? That is, the casting will not be scaled to any extent?

MR. BROPHY: We have had carburizing boxes, as I have said, in our own service, and we have had no trouble with cracking, in fact, to my knowledge we haven't had a failure of that kind and we have put out a considerable quantity of the alloy. We haven't had a failure from cracking. We have had a tube in operation for about three months, operating under conditions of about 900 degrees Cent. and holding considerable load. That tube was exposed, I believe, in three places, and the length of the tube is 13 feet, the diameter is 16 inches and has a 1-inch wall. I am sure it has a high tensile strength at high temperature because the tests we have made with it, other than tensile tests, have demonstrated that.

MR. MALONE: In your paper you mentioned the fact that at high temperature there is no attack on the material itself, after that first protective skin of oxide forms. You would say, then, that the metal would be good for a temperature of 1200 degrees Cent.

MR. BROPHY: We recommend using the alloy at about 1200 degrees Cent. and at about 2200 to 2300 degrees Fahr. It will stand higher temperatures, but of course with not as good life.

MR. ESTABROOK: Have you used this material in molten aluminum or molten brass?

MR. BROPHY: It won't hold molten aluminum. It will hold brass. We haven't had it holding brass; we have immersed samples in a bath of brass and there has been no appreciable attack, but aluminum goes right through it and lowers the melting point, so that the alloy will melt at a very much lower temperature. Antimony also attacks this alloy, but apparently with no bad effect; that is, the antimony alloys with it, it goes into the wall of the container, but with no bad effect.

MR. NORRIS: Referring to the attack of the antimony on the walls of these containers, does that have any effect in lowering or raising the temperature resistant quality of the metal?

MR. BROPHY: I imagine it would lower it. I really don't know. But when I said it had no bad effect, I meant the metal was still sound and strong. We did run for several hours after that attack and it had not oxidized appreciably.

MR. NORRIS: That mention of antimony reminded me of an article I saw a great many years ago to the effect that alloys of nickel, aluminum and antimony and iron had very high melting temperatures, and I was wondering when you mentioned the antimony content, whether it had any effect on the melting point.

MR. BROPHY: I don't know. I don't believe that would apply to all combinations of those elements. In the case of nickel aluminum, that compound melts at about 1600 degrees Cent., but, as is characteristic of all compounds, that is brittle as glass. It may be a similar case, that with the antimony it forms a high compound.

MR. PERCY WEDLAKE: Would you recommend using calite for protective tubes?

MR. BROPHY: We recommend it, but we don't like to cast around protective tubes.

MR. ESTABROOK: In your work on the zinc, did you notice any cracking in the zinc?

MR. BROPHY: I didn't notice it in the casting.

MR. B. H. DELONG: How does this metal stand handling in service? We have a tube for annealing steel; it is about 8 inches around and about 12 or 13 feet long. They roll out of the furnace while they are hot, say at 1200 degrees Fahr., and are dropped about 2 feet, which would knock off the protective coating in case they were brittle.

MR. BROPHY: What thickness of wall could that tube stand? If it were a thick wall, we would probably get away with it in good shape, but with a thin wall tube it would be difficult.

MR. BROWN: Have you any tests to show how this material stands up under high temperatures?

MR. BROPHY: Yes, sir. At 1300 degrees Cent. we have run calite for 216 hours in the open air without failure. After the 216 hours, we boosted the temperature to nearly 1400 degrees Cent. and ran it there for an additional 6 hours, and even after that there was no appreciable oxidation; the metal was sound after that. The nickel-chrome alloys, at 1250 degrees Cent. lasted 25 and 26 hours; two tests at 1250 degrees Cent. under the same conditions. As far as the amount of oxidation and the increase in weight is concerned, I will read from my original paper:

"On quenching after 100 hours at 1200 degrees Cent, calite lost but 0.03 gram per square centimeter exposed, while the best heat resisting base metal alloy other than calite lost 0.56 grams under the same conditions. The same samples were run at 1300 degrees Cent. for an additional 25 hours; calite lost 0.003 grams, the other 0.09 grams per square centimeter exposed." We have numerous other tests and they check that pretty well.

MR. W. M. MITCHELL: Might I ask under what conditions these tests were made?

MR. BROPHY: In the open air.

MR. MITCHELL: How were the temperatures taken?

MR. BROPHY: By lamp pyrometers.

MR. L. O. HART: Your results, Mr. Brophy, are taken from some casts we made. We took samples of calite and nickel chrome and put them in a quench running on tests of 1000 degrees Cent., and we found oxidation of calite at 1000 degrees Cent.

MR. BROPHY: Surely there is oxidation; there naturally would be, but that oxidation we depend upon for its protection. You mean you found excess of oxidation?

MR. HART: Yes.

MR. BROPHY: As I have said, we have had some failures; this alloy is not infallible; however, it is pretty good.

Discussion of V. E. Hillman's Paper

This paper, entitled "Cold Headed Bolts—Their Metallography and Heat Treatment," appeared on page 369 of the February issue of TRANSACTIONS.

MR. A. K. HAMER: I would like to say, Mr. Hillman, that we get a much better thread on our screws by annealing at 1150 degrees Fahr., than we do by annealing above 1150 degrees Fahr.

MR. HILLMAN: Very good results are produced at 1150 degrees Fahr. The only reason I didn't recommend it is because you are likely to get crystallization; isn't that true?

MR. HAMER: Yes, that is true, and we have found that we get a much better thread on bessemer steel than we do on basic. We find, of course, it is much harder on tools, but as far as the thread is concerned, we get a much better thread. The reason for this I don't know, whether it is the brittleness of the steel or what. These are wood screws I am speaking of.

MR. HILLMAN: I think that is to be expected because in your bessemer stock you have high sulphur and phosphorus, which promotes machinability. Of course, I will admit that with soft basic stock there is a tendency to tear, and you do not get the same machining properties as you would with bessemer steel.

MR. JOHN J. CROWE: Just what do you mean by crystallization? You say at the higher temperatures you do not get crystallization and at the low temperatures you do get crystallization. Does that mean the formation of grains?

MR. HILLMAN: By crystallization, as I have referred to it in this paper, is meant that you get an abnormal grain-growth if the metal is slightly strained and if you anneal within that hazardous zone. The micrographs which I showed, those that were taken of the large grains and of the smaller grains, were both taken of the same specimens. Crystallization in the wire industry is just simply, as I understand it, the creation of an extremely brittle condition in the metal, due to an abnormal grain-growth, and precisely the same condition takes place in both.

MR. CROWE: Don't you think it would be a little clearer is you used the term "grain growth" instead of crystallization?

MR. HILLMAN: I think so, yes; I gladly yield to that term. It probably would make it a little clearer.

MR. HOFFMAN: In all your annealing operations, then, I would take it that you carried them through the critical range, say 1650 degrees Fahr.; you didn't use any of the lower. You found in your work in cold heading bolts, that 1280 or 1300 degrees Fahr. was of no advantage; in other words, you got an absolute grain growth.

MR. HILLMAN: Yes; because in the same growth you are likely to have various degrees of distortion, and when your metal is critically strained and you anneal in this hazardous zone, you are likely to get you grain growth which will act as a seat of rupture only in that particular vicinity.

MR. A. W. F. Green: Why in annealing in the so-called hazardous zone of 1280 to 1550 degrees Fahr., do you get grain growth that is greatly strained? Is it because you have annealed the grain, or because of the relief of those zones, or what is it?

MR. HILLMAN: That is a peculiar characteristic manifested by all steels when the carbon is not above 0.20 per cent; sometimes not above 0.15 per cent. When you give it just a certain amount of strain and anneal

in that zone, you are going to get crystallization. In the wire industry if they drafted 12 per cent and annealed in this hazardous zone, they would get crystallization; isn't that right, Mr. Hoffman?

MR. HOFFMAN: In the wire industry they anneal at 1280 to 1300 degrees Fahr. and they don't get an absolute grain growth. The proposition is entirely different.

MR. GREEN: You have no theory to advance as to why it is so?

MR. HILLMAN: No, I didn't view it from that angle.

MR. GREEN: I simply asked the question for my own information.

MR. CRAWFORD: A few years ago Dr. Zay Jeffries performed some experiments on abnormal grain growth and found for every strain under 1280 degrees Fahr. in temperature there is a grain growth. I was wondering if it isn't possible that if you heat it at a lower temperature, your material strain at high percentages would grow. Have you noticed any other band or bands in a different position of your bolts than at these so-called critically strained parts? I don't believe there is any particular critical strain; I think that strain varies. You will get growth in different parts of the bolt, I believe. That is true of high sulphur steels, tungsten, molybdenum, ingot iron and a steel which we call standard iron which is an electrical steel.

MR. HILLMAN: Am I to understand that there is no place in steel at which you can depend upon this growth, no strain figure?

MR. CRAWFORD: For every strain below 30 per cent there is a temperature at which some part of the steel would grow. The rate of heating has an effect. If you heat rapidly, you will get growth in a very narrow band. In equiaxing you will get growth over a wider band. By heating rapidly, you don't give the steel an opportunity to recrystallize and you get a strain which is critical for the temperature at which you are heating.

MR. HILLMAN: You don't think that is a fixed quantity then?

MR. CRAWFORD: No. Of course, the question of large quantities of carbon will affect that; speaking of carbonaceous material for pure metal.

MR. HILLMAN: Briefly, what I understand by this grain growth is this: It is influenced first by the carbon content; second, by the amount of strain to which the metal has been subjected; and third by a treatment within a certain range, which is approximately 1280 to 1380 degrees Fahr.

MR. HOFFMAN: I believe the treatment in this case applied to elongated grain structures. You have really wrecked your grain structures; you have an elongated grain structure which at 1280 or 1300 degrees Fahr. begins to reform, whereby you get a new structure. But that grain growth is not completed until you get to the critical point, which is in your case around 1600 degrees Fahr. You don't have a complete grain growth at 1300 degrees Fahr., but you do have a beginning of the new structure.

MR. HILLMAN: You don't think the micrograph I showed was complete; it would have become larger?

MR. HOFFMAN: Not unless you carried them up to 1600 degrees Fahr. Several of them weren't complete.

MR. A. L. DAVIS: I think that this is a most interesting point; it is one that many of us have been up against at one time and another. In its reaction below the critical range of 1600 to 1650 degrees Fahr., mild carbon steel strictly can be compared with nonferrous alloys, where we have exactly that phenomenon of an abnormal grain growth developing in the case of slightly strained metals. For instance, of you take a piece of zinc and bend

and then heat it, you can see enormous grain form before your eyes; the temperature is so low that no oxidation takes place. It is a common characteristic in brass too.

In steel, as has been brought out, for every degree of deformation there would be a critical range in which abnormal grain growth would take place if heating was sufficiently prolonged in that range. Chappelle, by the way, shows this very well on pieces of a tensile test specimen which, on being pulled out, has elongated and has strained more and more as it decked down, and where it broke, has been most strained. Annealing in his case was 650 degrees Cent., which I think is somewhere around 1200 degrees Fahr. There was a certain range in that tapering test piece, representing different amounts of cold work, where the abnormal grain growth did take place. Had he annealed at some other temperature, that zone would have been moved up or down on the tapering section.

But I think you practically put your finger on the point when you say 1280 to 1380 degrees Fahr., because they represent the temperature conditions applying to a very slight degree of deformation, and it is in the case of slight deformations where abnormal grain growth will take place quite rapidly.

Departing from that for a moment, I wanted to ask about something that was not quite clear to me. In the refining and annealing by heating above the transformation temperature to 1650 degrees Fahr., you speak of annealing and quenching. Is that preferable to heating and allowing to cool naturally in air? I am asking as a matter of practical experience that you have had.

MR. HILLMAN: I think it is.

MR. DAVIS: You get possibly a greater stiffness, do you?

MR. HILLMAN: No, I don't think there is any response to the heat treatment, but it probably arrests the grain particles in some particular size.

MR. DAVIS: My reason for asking that question is this: While we know, of course, that mild carbon steels won't harden in any true sense of the word, when quenched from 1650 degrees Fahr., we do know that even with the lowest carbon steels there is a little tendency to show a greater hardness than measured by Brinell or Shaw, and unless I am mistaken, when such stiffened specimens are subsequently cold worked, they react very rapidly in their hardening, in their increase in hardness under the effect of cold work. I would have thought that there might be an advantage on that account, in allowing the annealed blanks to cool in air, rather than cooling in water. As I haven't actually carried this out commercially on that sort of work, I offer it in the sense of a question rather than a statement.

MR. HILLMAN: I would ask Mr. Hoffman to give us something in answer to that.

MR. HOFFMAN: The theory there is really arresting the growth in the critical range.

MR. HILLMAN: Is that what you do when you quench?

MR. HOFFMAN: Absolutely.

MR. ANCEL ST. JOHN: A very recent article by Dr. Jeffries which I think it is in the current number of *Chemical and Metallurgical Engineering,* throws considerable light on this question of crystallization, as Mr. Hillman has called it, or grain growth within a very restricted range. I have not read the article in question, but I am familiar with the subject matter of it. Dr. Jeffries shows that the temperature limits within which grain growth

occurs are very narrow, that is, they may be even narrower than the 100 degree range that Mr. Hillman has mentioned; that for any particular degree of working there is a particular temperature range within which the grain growth will be remarkably rapid and large grain size will be obtained in a very short time, whereas if you fail to heat to that temperature, you do not get the grain growth, or if you heat through that temperature, going through the zone too rapidly for any grain growth to occur, the growth does not occur at the higher temperature. Therefore, in this whole question it would be very desirable to obtain access to the data that Dr. Jeffries has made available. Probably you would find in it the answer to a number of your difficulties. It is the restriction within very close limits of the temperature at which the soaking is carried on.

MR. R. G. HALL: Mr. Hillman, I would like to ask what kind of steel you used in your dies?

MR. HILLMAN: I am not familiar with the steel that was used. I obtained the specimens from bolt manufacturers and consequently I am not in a position to state what their practice is.

MR. E. E. THUM: I would like to supplement what Mr. St. John has just said and call attention to some recent English work on the recrystallization of aluminum. It is rather far fetched, but it is merely another instance of a metal which is popularly supposed to be quite difficult to recrystallize, being in fact quite easy to crystallize if you had the proper amount of cold work and the proper temperature.

Professor Carpenter has been able to convert an entire test piece into a single crystal, and has done it not once but one hundred or more times. That is to say, a standard size test piece has been converted into a single crystal of aluminum, some 10 to 15 million times as big as the crystals which originally comprised the piece.

I would like to ask Mr. Hillman a question regarding his Fig. 15. There is a very curious lance-like structure shown there. This piece was etched with nitric acid, I presume?

MR. HILLMAN: No, copper ammonium chloride.

MR. THUM: You say that you polished that yourself for quite some time. Did you notice these lance-like structures early in the polishing?

MR. HILLMAN: No, I didn't notice them until afterwards.

MR. THUM: Why did it take so long to polish them? Ordinarily one would not expect to polish a sample for several hours before he got a sizable job, and I merely wanted to suggest that perhaps these lance-like structures would not polish out because they were caused by cold-working the rod before it got into your hands. Those lance-like structures are very much like cold-working figures which can be had and developed in ordinary low carbon steels by merely rolling them a little too cold, or finishing them a little too cold.

MR. HILLMAN: In this micro-etching, we first polish for an hour and etch, and if we do not get the pattern that we think we should get, we polish for another hour. I continued that polishing for 6 to 7 hours until I obtained that whirlpool-like appearance at the center of the head. It isn't always easy to develop these patterns the way they should be developed. I did not notice those lance-like structures until probably after the fifth or sixth polishing.

MR. DAVIS: Were you using a cold-drawn rod or an annealed rod?

MR. HILLMAN: It was basic soft, given one pass after the anneal.

In further reference to your question, this combination is developed by a combination etch and polish, so that is why we had to continue it until we got what we desired to get. It isn't as good a picture as I would have liked to show, but it is the best I could get under the circumstances.

MR. WHIGG: When you refer to the possibility of showing these etched figures in previously strained metal, I think there was a publication from one of the German technical magazines recently noticed in our press. I think it was found in December in the *Iron Age*, in which there were very carefully picked out details given, showing how it was possible to develop these etch patterns in strained iron and steel. The problem is of such interest that it is to be hoped that American metallurgists will look into the matter. I don't remember the details now, but as I recall the previously strained metal is given an anneal for from 20 minutes to 1 hour, then it is polished and etched with a modified Hines reagent. The bended strips and these cold worked strips develop certain definite measures which are susceptible of mathematical analysis as indicating the strain effects that have taken place in the members or the test piece.

As I say, I haven't had an opportunity yet to do any work on the method, but there is a possibility that it will open up new fields of investigation along certain lines—the examination of failed members, etc.

MR. DAVIS: You make a statement as to the effects of cold work in general, in which you speak of increased tensile strength, elastic limit, and so on, with decreased ductility. You mention specific gravity increasing with the working. I wonder if I might not take exception to that, that the density does not increase with cold work but decreases considerably. I think that it is a well sustained fact that most metals on cold work, unless they are spongy and porous to start with, become slightly increased in volume and therefore slightly less split up.

MR. HILLMAN: Aren't the crystals rendered more compact?

MR. DAVIS: No, I think actual experiment will show not. Cold-worked metals of all kinds tend to increase in volume rather than decrease.

MR. HOFFMAN: Then, Mr. Davis, I would understand you to say that if you had strained a low carbon steel through cold work or any other method, that you could not recrystallize that and get an original grain structure; is that the idea?

MR. DAVIS: No, I wouldn't say so; but in its cold worked condition it would be slightly less dense than it would be after you had reannealed it, or at the outset before it had been cold worked. It is contrary to the natural thought that any one would have on the subject, but I believe it is sustained everywhere by careful experimentation that specific gravity always decreases slightly as the result of very considerable cold work.

MR. HOFFMAN: Have your own experiments borne that out?

MR. DAVIS: Yes, in brass. I have not found it in steel, although I understand that is so recorded by scientific investigators.

MR. HILLMAN: Scientific investigators record that the specific gravity increases in steel.

MR. DAVIS: The specific gravity of hot worked steel over that of cast, but not when you come to cold work.

MR. WIZENAK: Regarding that proposition, I had that point taken up with Professor Sauveur of Harvard, recently, and he bears out Mr. Davis' statement. It was also contrary to my own belief. I had a class and

that question came up, and it was surprising to come across that problem. I took the question up with Professor Sauveur and he made a statement to that effect. It does not seem to be consistent with general belief, but nevertheless that is the opinion of Professor Sauveur.

Discussion of J. H. G. Williams' Paper

This paper, entitled "Perfecting a Drop Forging," appeared on page 391 of the February issue of TRANSACTIONS.

MR. W. H. SAWTELL: I would like to inquire how the flash traveling back into the stock was overcome from the stock in the center of the pieces?

MR. WILLIAMS: We were going to change the shape of the edger impressions, but in the meantime the man on the hammer omitted the use of the edger impression and put the bar stock directly into the roughing impression. He found the blank was not thrown; in other words, all the money that we had put into the sinking of these impressions was money thrown away. The hammer man himself overcame that defect by omitting the edger impression.

MR. SAWTELL: How about the part out near the edge of the center?

MR. WILLIAMS: I should have mentioned that. There are three ways of overcoming that defect. In the first place, you can punch out the central part before the final blow and make room for the excess metal to flow into; or you can, in your rough forging operation forge the center thinner than we did in this case, so that there would be a space left when the finishing impression came down for the metal to flow into. As a matter of fact, we cut a gutter in the finished impression, in the central part of the finished impression, thereby creating a space for the excess metal to flow into, and that would be the ordinary procedure in a case of that nature simply make some provision for affording extra space for the metal to flow into.

MR. A. H. d'ARCAMBAL: To what extent do you use a deep-etch test in inspecting incoming material?

MR. WILLIAMS: That depends considerably upon the forging upon which we are going to use the steel. If the forging is a steam hammer job or a job for a heavy hammer where the hammer expense itself is heavy, it is naturally an expensive operation to make forgings and reject them. In cases of that sort we have developed a rather elaborate inspection system, which involves the pickling of a representative number of bars for outside service inspection and also, particularly on jobs with the steam hammer, of cutting a few slabs, usually about one-half inch thick, we will say, two or three to a heap, and subjecting them to the deep-etch test. We find that this test is invaluable in catching stock which is segregated, stock in which the sulphur has not been properly disseminated, dirty steel, and steel which lacks homogeneity.

MR. d'ARCAMBAL: Do you have much trouble having the steel mills take the stock back when you deep-etch?

MR. WILLIAMS: No, we never have any trouble. As a matter of fact, we buy what is called double selected stock. I would say that double selected merely means, from my own observation, that if you

find something wrong, you have the privilege of selecting it, whereas if you bought mill run, you take a gamble.

MR. d'ARCAMBAL: There is quite a difference, of course.

MR. WILLIAMS: Our treatment has been very satisfactory, that is, the treatment given us by the steel company has been very satisfactory.

MR. R. H. REIMAN: Do you make the breakdown operation and the finishing operation in the same die, that is, on the same block and in the same heat?

MR. WILLIAMS: Usually, yes. Of course, the size of the forging and the shape of the forging controls that. In a crankshaft forging probably you would make your breakdown under a hydraulic press, at least we do, and our rough blanking forging under one steam hammer and the finishing impression under another steam hammer. When you get into this heavy steam-hammer work, it is rather hard on the piston rods to put any heavy duty on an impression which is over the edge of the dies. It throws a side strain on the rods.

MR. REIMAN: What do you do in this particular case. (Designates a particular forging).

MR. WILLIAMS: The three impressions are on one set of the dies; the breakdown on the edge, the roughing impression on one side and the finishing impression on the other side. It is quite a question in shop economics sometimes to decide whether you will use one impression, two impressions or three impressions. Many factors are to be considered. If you have a long run, naturally you want to save your finishing impression as long as you can and throw the wear into your roughing impression. If you have a short run and no chance of a repeat order, you want to hold your die cost down and you make it a one-impression job.

Discussion of E. J. Janitzky's Paper

This paper, entitled "New Development on the Influence of Mass in Heat Treatment," appeared on page 377 of the February issue of TRANSACTIONS.

MR. JANITZKY: The author desires to supplement the information given in the original paper. This additional information belongs properly after the second paragraph on page 377 ending with the words "and outside of rounds on their cross sections."

In regard to this, it may be said that this holds good not only for ordinary structural steels, but also for air hardening steels. The paper does not contain that fact, but further experiments revealed it.

A second substitution should be made after the fourth paragraph on page 377 ending with the words "a multiple of the square of the hardening capacity."

It has been found that in some air hardening steels the factor is 9; in certain others it is 7, but for ordinary structural alloy steels, it seems to be 2.

Data regarding the air hardening steels mentioned in the paper is given in the following two tables:

(1). *High nickel-chrome steel quenched in water at* 1510 *degrees Fahr.*

The composition of the steel was carbon 0.29, manganese 0.37, nickel 2.22 and chromium 0.97 per cent.
$BM = 512$, $b = 196$, thus

$$n = 7 \left[\frac{BM}{b}\right]^2 = 47.7$$

Center Data

$$B = \frac{(14.125)\ (47.7)}{D - (-1.255)} + 196$$

The following results were obtained:

Diameter of section inches	Actual Brinell Hardness	Calculated Brinell Hardness
0.5	512	...
0.875	...	512.
1.0	495	495
2.0	418	403
2.5	387	376
5.0	...	294

(2). *High nickel-chrome steel, S.A.E. specification* 3440, *quenched in water at* 1450 *degrees Fahr.*

The composition of the steel was carbon 0.42, manganese 0.30, nickel 3.18, and chromium 0.81 per cent.
$BM = 555$, $b = 197$, thus

$$n = 9 \left[\frac{555}{197}\right]^2 = 71.35$$

Center Data

$$B = \frac{(71.35)\ (14.125)}{D - (-1.47)} + 197$$

The following results were obtained:

Diameter of section inches	Actual Brinell Harnesss	Calculated Brinell Hardness
0.5	555	...
1.0	546	...
1.35	...	555
2.0	487	487
3.0	420	422

MR. JANITZKY: Referring to Sir Robert Hadfield's criticisms appearing on page 396 of the February issue of TRANSACTIONS, Mr. Hadfield says that I took a physical basis as my hypothesis. I dont see where I could have taken any other one. Should I have taken a metaphysical one? I could it has been proven that the important factor in heating, cooling and hardening is the surface. That is the reason I took a physical basis, a real one, which can be measured and from which there can be obtained a definite idea about things that have some connection with hardness.

In the second place, he says he doubts whether the Brinell hardness de-

creases with increase in surface according to a straight line. I can say definitely that if you plot the Brinell hardness against the surface in pounds per square inch, you will get a straight line. As long as he questions it, he should not just simply shake his head, but should bring evidence that I am wrong.

I think the proof of the pudding is in the eating. I have given figures for alloy and air hardening steels that check wonderfully. I don't think that we need to be in doubt about this question in regard to the direct ratio between Brinell and surface.

I can't understand exactly what Mr. Hadfield means regarding his figures, namely, "water quenched value of b=214.4, and water quenched value of d=0.49." We could take the annealed condition of b for every steel, but as I stated in the paper, our calculations show that for engineering purposes, the formula works better if b is taken as the hardness of the steel in the normalized state.

In regard to d I would like to say that everybody knows that a hyperbola has two asymptotes, and therefore, d and b are essential parts of the formula, as both represent the asymptotes of the curve. I can't figure a hyperbola without a d. Further, d is not an assumed proposition; it is a function of n, and n we know is the function of the hardening capacity and changes in multiples in connection with the sensitiveness of the steel. These factors have to be exploited and constants found which will work on an engineering basis. A criticism of d is superfluous.

Further, Mr. Hadfield has said that he hopes that others will investigate the subject. It is hoped that someone else will investigate my data and offer criticism based on actual experiments.

I wish to call attention to an error in the printing of the paper. On page 381, in the first table on the page, the figure for the "Actual Brinell hardness" of the 3-inch round should be 248, instead of 348.

Discussion of A. V. deForest's Paper

This paper, entitled "Magnetic Testing of Small Case Hardened Chain," appeared on page 387 of the February issue of TRANSACTIONS.

MR. A. V. DEFOREST: Toward the beginning of the war there was a pleasing picture in *Punch*, depicting a corps of German professors testing war bread, and the first test was its rust resisting properties in sulphuric acid, and the next one was its electrical conductivity at 100 degrees, and then they measured its properties as an insulator, and after that they carried it up to the top of the building, dropped it off and found out how long it took to reach the ground. Now, those tests were supposed to be humorous, but if you go back a step further than that, you get the basis for the tests I am going to show you.

We have, more or less, two different types of tests: The type which approximates working conditions and which therefore gives properties that are directly interesting—the tensile test and the shock test and sometimes the hardness test are all of that class. Then there is another class of tests which were evidently the ones that the German professors were trying—a test which measures something or other, which does not necessarily have any connection whatever with the use to which the material is

to be put, but yet which varies with some property of the material which does influence its usefulness.

There are infinite properties belonging to most materials; there are all sorts of things that can be measured in regard to almost anything, and there is a possibility of using any one of those, if it happens to coincide with a useful change in the material. This magnetic affair is of no particular interest to hardened cross chain; nobody uses hardened cross chain in electrical machinery, but nevertheless it happens that the magnetic qualities change very closely, proportionately, to a particularly useful quality in the chain.

We found, on looking over chains that had worn, that both those that were too deeply cased and those that were too little cased were unsatisfactory. The too deep case is so brittle, it may break long ahead of its proper life; the too soft one will wear out after a fair length of life but before the proper one. Therefore we were interested in getting the right depth of case and knowing it.

The previous method of breaking the link, of looking at it and guessing from its appearance how deep the case was, is not particularly satisfactory; it limits the amount that can be examined and it takes too long and it costs too much, for a real, proper check. When we got a method that would do that quickly and non-destructively, we found that we could raise our quality very much indeed simply by having a test that worked rapidly and with a sufficient degree of accuracy.

Why the thing works, I don't know, and it seems almost beside the point. The relation is simply that it has been established by practical tests that it does measure something which is akin to the life of the chain. With one test only, that is, measuring on a single scale with a single arrangement of circuit, you get a reading which does not necessarily mean a particular depth of case; it varies with the carbon of the base stock and with the heat treatment that it has received, whether it is quenched from the pot or whether it is cooled and reheated and quenched again, but it is more or less proportional to the hardness or to the brittleness, if we like to say that, and to the wearing ability of the chain.

MR. A. H. d'ARCAMBAL: How would a chrome vanadium steel around 0.40 per cent carbon serve for skid chains? I think you could quench and get a better wearing.

MR. DEFOREST: So far we haven't obtained enough service to pay for the cost of welding, that is, to pay for the better stock and for the welding. After we have made our chain of that, it does not wear enough to pay the extra cost of the stock itself.

MR. d'ARCAMBAL: Of course, your heat treating proposition would be much better than the carburizing.

MR. DEFOREST: That is true, but the heat treating itself does not seem to work out better in the results, from the work we have done.

MR. A. L. DAVIS: Have you ever tried the 13 per cent manganese steel?

MR. DEFOREST: We have tried that without the success which we had hoped for. After the labor and difficulty involved in getting that into a chain, it does not do what it is expected to do, although I find it is recognized that the steel, if it is punished hard enough, will wear about like ordinary low carbon. On the road it behaves very much like a 0.10 per cent carbon steel without any carbonization at all.

MR. C. O'NEILL: Have you tried the 1.25 per cent manganese steel that was used for the cast steel chains during the war?

MR. DEFOREST: I don't think we have tried that. It would be interesting.

MR. O'NEILL: There have been some very interesting results on chain of the composition that I mentioned.

MR. DEFOREST: It is rather interesting if you can get it in the shape so that you can handle it. It is rather difficult to handle, I believe.

MR. F. P. FAHY: May I refer to a point in your paper? It reads: "So far, the magnetic result has given a pretty close idea of brittleness of the chain, whatever that may mean. If now another variable is brought in, the drawing temperature results are not as good." I would like to inquire whether that means that this particular apparatus is not workable if this additional variable, the drawing temperature, is brought in?

MR. DEFOREST: We have made magnetic tests on this principle, in which we were interested in the drawing temperatures and in which we did measure them separately from the other state of the steel. It is not quite as simple or as easy as this thing is. Naturally, it means two measurements instead of one, we are going to find out two things instead of one, and if one, as in this case, does the trick, we are well pleased. It can be done. We are doing it.

MR. W. F. GRAHAM: Regarding the application of this method of magnetic testing to a straight carbon tool steel, of a sufficient section that would not harden all the way through, I was wondering if your method would give you an indication of its hardness or its brittleness. If the outside skin of the metal was sufficiently hard for our purposes, if a straight carbon section of sufficient carbon steel would not have a martensitic zone and then the interior would not be martensitic, could you get any indication on material of that kind?

MR. DEFOREST: I believe we could if we had all the factors except the one remain constant.

MR. W. H. SAWTELL: Do I understand that tools of high carbon steel can be tested by this process?

MR. DEFOREST: Very readily.

MR. SAWTELL: Practically any hardness of any sort of steel?

MR. DEFOREST: Yes.

MR. SAWTELL: Some tests, I imagine, have to be run originally, to get the material to work from.

MR. DEFOREST: You have to compare with standards that have to be the high ends to whatever limit you like and the low end to whatever limit you like, but simply use it as a no-end gage.

MR. SAWTELL: It would seem to me that that would have a large use, then, in the steel trade.

MR. DEFOREST: I hope that it will.

MR. E. F. CONE: In working with magnetic testing, have you been able to correlate any other physical properties besides hardness, or do you think it would be possible to do that?

MR. DEFOREST: That is quite a question. We have been able successfully to arrange the test to fit several different factors in the usefulness of the steel the tensile strength, we will say, and the elongation are mutually dependent, but not necessarily exactly so, because you can have a certain tensile strength with and without a certain elongation, depending on the other factor, the composition of the steel. We can handle

up to two factors we know about. The others are a bit vague and it becomes very complicated when you try to handle three factors at once. However, there is no reason why it can't be worked out. We can't go to the magnetic test and pick out hardness or tensile strength or brittleness, or anything else directly; we have to take an aggregate of factors and in some way fit a test to the particular results that we want, knowing the results beforehand from working tests.

MR. P. R. LAFORE: A few minutes ago there was some mention made of costs of the process of case hardening. I wondered what method you used, whether you pack or use some other method?

MR. DEFOREST: These are case hardened in one of the numerous compounds.

MR. LAFORE: Do you use a furnace?

MR. DEFOREST: We use a furnace.

MR. LAFORE: Is it practical?

MR. DEFOREST: It is a practical way to do it, especially if you desire uniformity.

PHYSICAL TESTS ON HIGH SPEED STEELS

By A. H. d'Arcambal

A SEARCH of the literature on high speed steel, shows that very little information has ever been published on the strength of high speed steel given different heat treatments. Believing that such information is of sufficient value to merit work along these lines, the writer recently has completed a series of tensile and transverse tests on the two classes of high speed steel finding the widest use in this country, namely, the 18 per cent tungsten, 1 per cent vanadium type and the 14 per cent tungsten, 2 per cent vanadium grade.

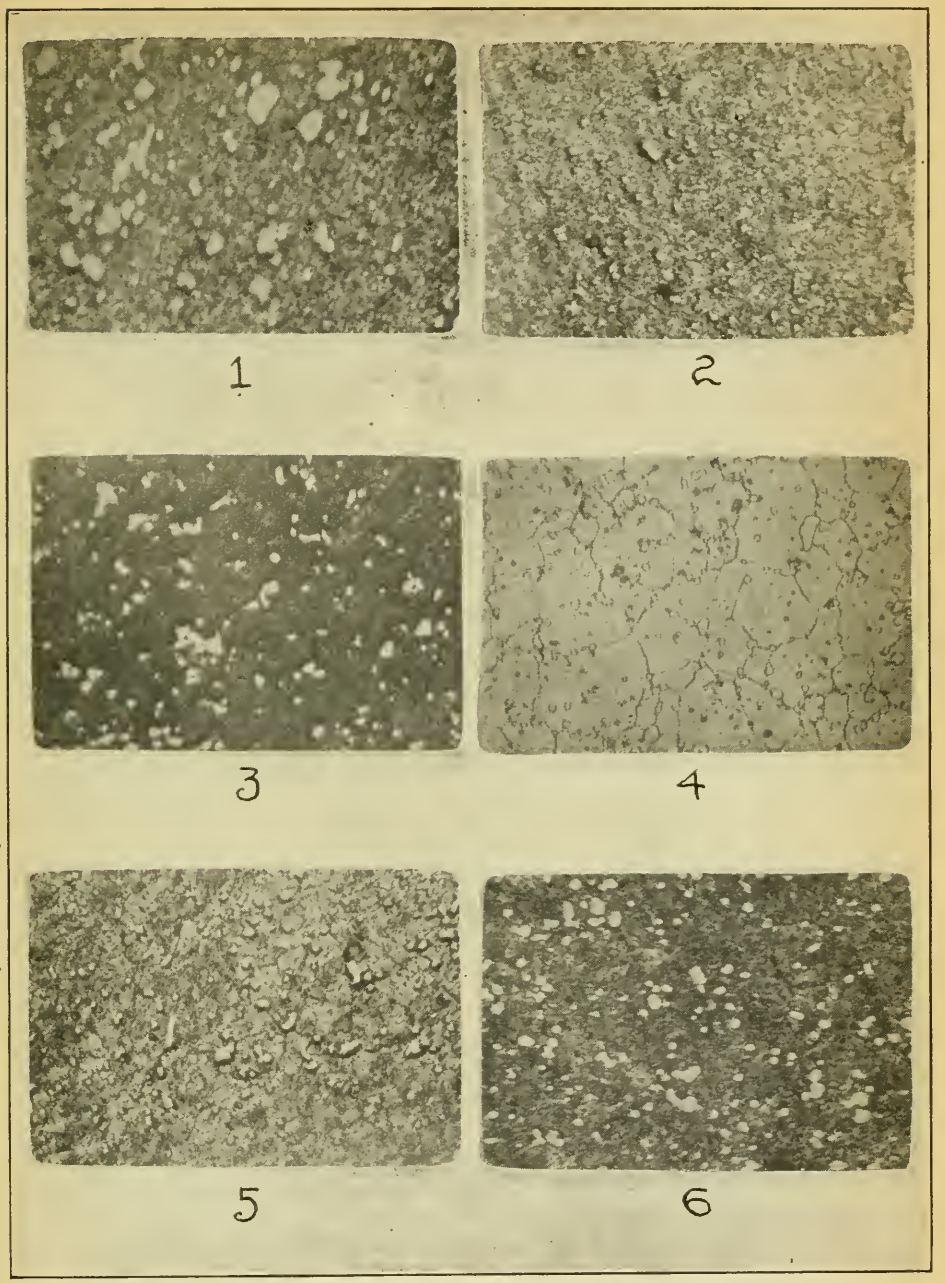
Hot rolled and annealed bars ¾-inch round were used for the transverse specimens, the analysis of the material running as follows:

	Grade *A* per cent	Grade *B* per cent
Carbon	0.63	0.65
Chromium	3.55	3.33
Vanadium	0.97	1.78
Tungsten	17.04	13.85

These bars were cut into 7-inch lengths, centered, and turned to 11/16-inch in diameter. They were given the different heat treatments shown in Table I, then carefully ground to 21/32-inch diameter. The transverse figures obtained on these different specimens are shown in Table I and the micrographs in Figs. 1-17. The fractures were also examined, and it was noted that the fractures on the specimens of grade *B* steel, quenched from 2350 degrees Fahr. showed a slight coarsening of the grain; the fractures on the grade *B* samples quenched from 2100 degrees Fahr. and all of the grade *A* specimens possessing a velvety appearance. All of these transverse samples were also tested for hardness, using flat temper testing Nicholson XF files. The only specimens too soft to the file were the samples of grade *A* and grade *B* steels quenched from 2100 degrees Fahr. and given the 1100 degrees Fahr. draw. One is led to draw the following conclusions from these tests:

1. The heat treatment giving the greatest fiber stress together with the requisite hardness was that of quenching from 2350 degrees Fahr. into the lead bath at 1100 degrees Fahr., cooling to room temperature, and drawing to 1100 degrees Fahr. Quenching from the high temperature into an oil bath, and drawing to 1100 degrees Fahr., gave almost as high results as the specimens quenched into the lead bath, and given the high draw. On tests conducted several months ago, transverse specimens made from high speed steel similar in analysis to grade *A* steel, were quenched from 2300 degrees Fahr. into oil and drawn to 1100 degrees Fahr. These specimens gave a fiber stress of 550,000 pounds to the square inch, two and one half times the strength of samples from the same bar quenched from the same temperature, but only drawn to 450 degrees Fahr. The author believes that if the specimens quenched from 2350 degrees Fahr. had been drawn to 1150-1175 degrees Fahr., the fiber stress obtained on the grade *A* steel would have approached quite closely the strength of the samples given the 2300-1100 degree Fahr. treatment, and would also have possessed the necessary hardness, because of the higher quenching temperature.

A paper presented at the Indianapolis Convention. The author, A. H. d'Arcambal, is chief metallurgist, Pratt & Whitney Co., Hartford, Conn.



Figs. 1-6—Micrographs of grade *A* transverse series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 1—Longitudinal section, annealed condition. Fig. 2—Cross section, 2100 degrees Fahr. oil quenched, not drawn. Fig. 3—Cross section, 2100 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr. Fig. 4—Cross section, 2350 degrees Fahr. oil quenched, not drawn. Fig. 5—Cross section, 2350 degrees Fahr. oil quenched, drawn to 450 degrees Fahr. Fig. 6—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr.

2. Specimens of grade *A* steel, quenched from 2350 degrees Fahr. into oil and not drawn and samples quenched from the same temperature into the lead bath at 1100 degrees Fahr., air cooled and not drawn, showed a fiber stress of only a little more than one-half that of specimens given the same quenching treatment but drawn to 1100 degrees Fahr. Some of the undrawn specimens developed small cracks after grinding, due to the strains in the material. Every specimen made from grade *B* steel, and quenched from 2350 degrees Fahr. into oil or lead and not drawn,

Table I

Transverse Stress Tests

Analysis of Material Used

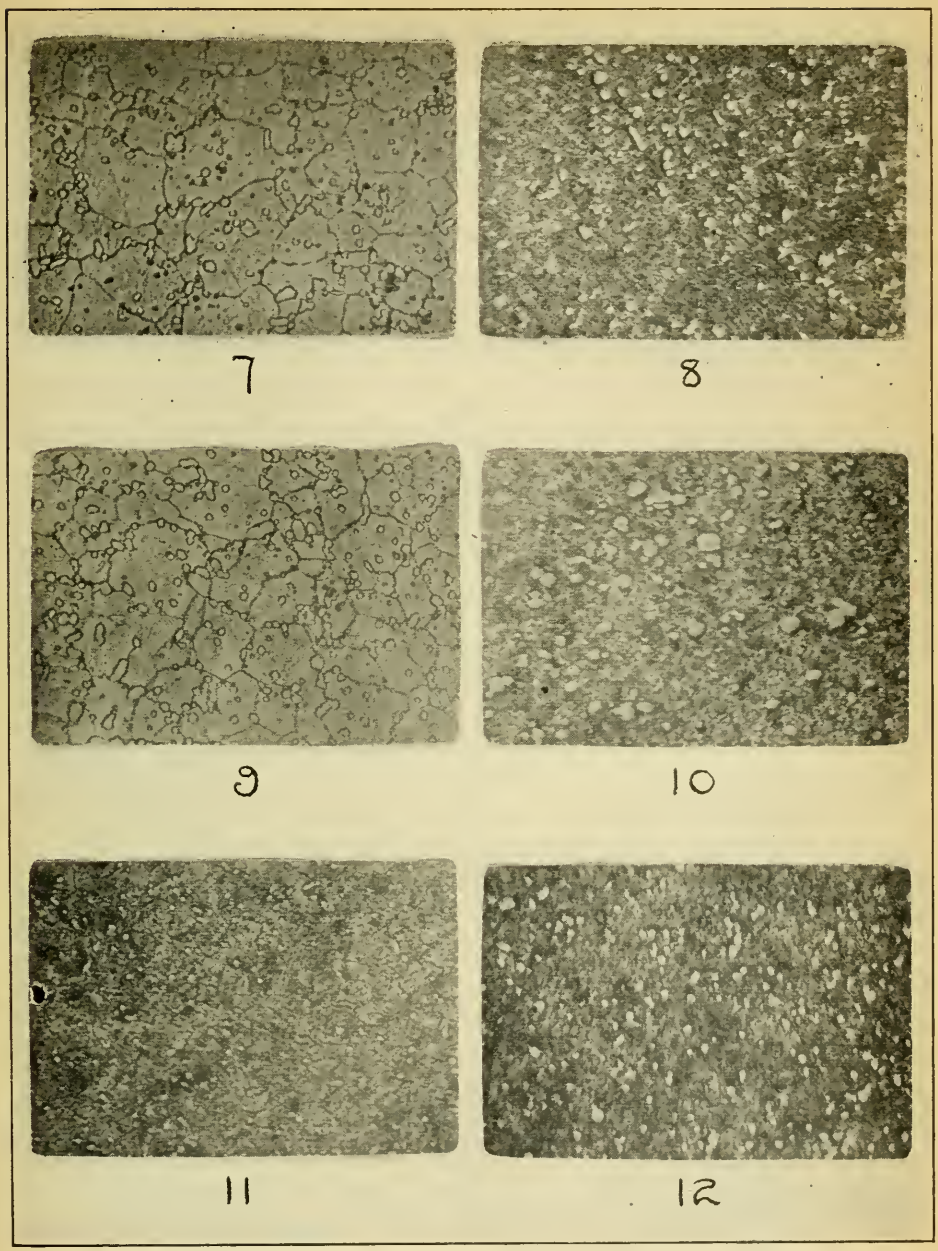
	Grade *A* per cent	Grade *B* per cent
Carbon	0.63	0.65
Chrominum	3.55	3.33
Vanadium	0.97	1.78
Tungsten	17.04	13.85

Specimens—0.656 inch diameter x 7 inches long.

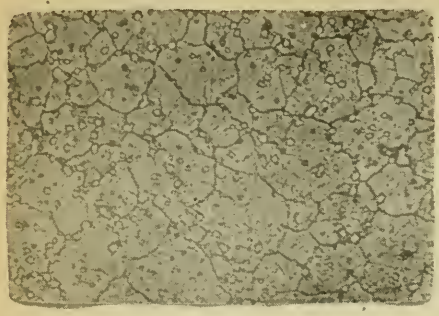
Heat Treatment	Approximate Fiber Stress Grade *A* pounds per square inch	Grade *B* pounds per square inch
2100 degrees Fahr. Oil quenched, not drawn	302,000	330,000
2100 degrees Fahr. Oil quenched drawn to 1100 degrees Fahr.	460,000	520,000
2350 degrees Fahr. Oil quenched, not drawn	250,000 Few small grinding cracks present	Full of grinding cracks, so not tested
2350 degrees Fahr. Oil quenched, drawn to 450 degrees Fahr.	308,000	222,000
2350 degrees Fahr. Oil quenched, drawn to 1100 degrees Fahr.	401,000	378,000
2350 degrees Fahr. Quenched into lead at 1100 degrees Fahr. then air cooled. Not drawn	243,000	Full of grinding cracks, so not tested
2350 degrees Fahr. Quenched into lead at 1100 degrees Fahr. air cooled then drawn to 1100 degrees Fahr.	432,000	396,000
2350 degrees Fahr. Quenched into oil until spec. was cooled to about 1100,degrees Fahr. then air cooled. Not drawn	243,000 Few small grinding cracks present in one of the specimens.	

developed so many grinding cracks that they could not be tested. The undrawn specimens of both grades of steel were ground with the utmost care, for from tests conducted in the past, it was discovered that the specimens given the high quenching temperature, 2300 degrees Fahr., and not drawn all cracked in grinding. It was impossible, however, to grind all of the undrawn specimens from grade *A* steel without cracking a few, and we were not able to obtain an undrawn specimen of grade *B* steel that was not full of grinding cracks. This high drawing treatment, therefore, not only produces about double the strength over that of undrawn specimens, but also gives a greater factor of safety in grinding.

3. Grade *B* specimens quenched from 2350 degrees Fahr. and drawn to 450 and 1100 degrees Fahr., do not possess as high a transverse strength as grade *A* specimens given the same hardening treatments. It would appear that grade *B* steel does not stand as high a quenching temperature as grade *A* steel, for the fracture on the grade *B* specimens,



Figs. 7-9—Micrographs of grade *A* transverse series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 7—Cross section, 2350 degrees Fahr. quenched in lead at 1100 degrees Fahr., then air cooled, not drawn. Fig. 8—Cross section, 2350 degrees Fahr. quenched in lead at 1100 degrees Fahr., air cooled then drawn to 1100 degrees Fahr. Fig. 9—Cross section, 2350 degrees Fahr. quenched in oil until cooled to about 1100 degrees Fahr., then air cooled, not drawn. Figs. 10-12—Micrographs of grade *B* transverse series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 10—Longitudinal section, annealed condition. Fig. 11—Cross section, 2100 degrees Fahr. oil quenched, not drawn. Fig. 12—Cross section, 2100 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr.



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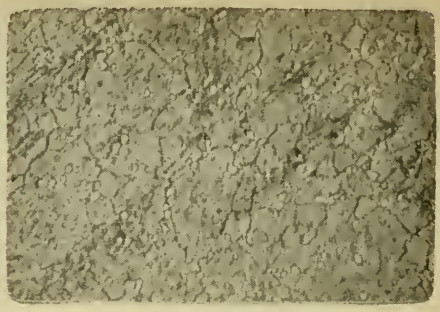

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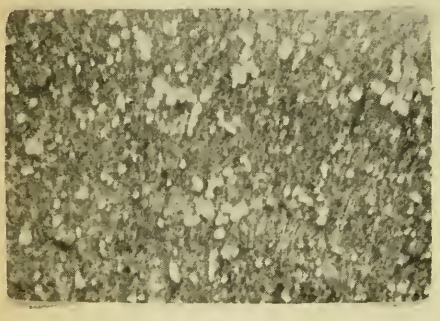

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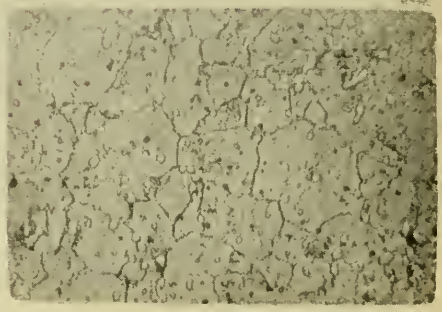

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Figs. 13-17—Micrographs of grade *B* transverse series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 13—Cross section, 2350 degrees Fahr. oil quenched, not drawn. Fig. 14—Cross section, 2350 degrees Fahr. oil quenched, drawn to 450 degrees Fahr. Fig. 15—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr. Fig. 16—Cross section, 2350 degrees Fahr. quenched in lead at 1100 degrees Fahr., then air cooled, not drawn. Fig. 17—Cross section, 2350 degrees Fahr. quenched in lead at 1100 degrees Fahr., air cooled, then drawn to 1100 degrees Fahr. Fig. 18—Micrograph of grade *A* tensile test series. Longitudinal section, annealed condition. Etched 3 minutes in 5 per cent nital and X 465.

quenched from the high temperature, showed a slight coarsening of the grain. The author believes that grade *B* specimens quenched from 2300 degrees Fahr. and drawn to 1100 degrees Fahr. would show at least as great a strength as grade *A* specimens given the 2350-1100 degree Fahr. treatment.

4. The micrographs, Fig. 1-17, show that the material as received in the annealed condition, was satisfactory. Specimens of both grades of steel quenched from 2100 degrees Fahr. and not drawn showed a fine grained martensitic structure with free carbides and tungstides. Drawing to 1100 degrees Fahr. into oil or lead and not drawn possessed the polyhedral structure of austenite with only a few undissolved carbides and tungstides. Drawing to 450 degrees Fahr., in case of the *A* grade, leaves only a trace of the polyhedral structure, while the *B* specimens still showed a well developed grain. It would thus seem that the *B* type

Table II
Additional Tensile Tests

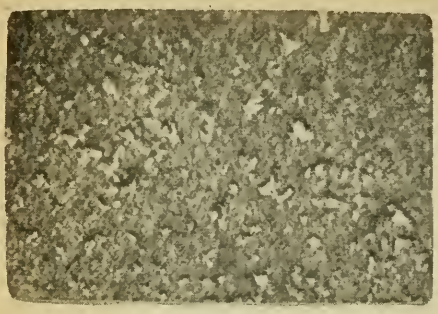
Heat Treatment	Temperature at which tested, degrees Fahr.	Tensile strength pounds per square inch
Grade *A* High Speed Steel		
2350 degrees Fahr. Oil quench, not drawn	Room temperature	175,000
2350 " " " " " "	800	272,000
2350 " " " " " "	1100	225,000
2350 degrees Fahr. Oil quench, 450 degrees Fahr. draw	Room temperature	185,000
Carbon Tool Steel		
1460 degrees Fahr. brine quench, 400 degrees Fahr. draw	Room temperature	183,000
1460 degrees Fahr. brine quench, 400 degrees Fahr. draw	1100	65,000

of steel requires a higher drawing temperature to produce the same changes in microstructure than is required by the *A* grade. It is also interesting to note the extremely low fiber stress on the *B* grade drawn to 450 degrees Fahr., in comparison with the *A* grade given the same heat treatment. Micrographs of both grades of steel, drawn to 1100 degrees Fahr. show a complete disappearance of the polyhedral structure of austenite, and the development of a full martensitic structure. This structure is the most desirable one, for material possessing this microstructure has the greatest strength, proper hardness, and greatest degree of red hardness.

One and three-sixteenths inch diameter hot rolled and annealed bars of high speed steel were obtained for the tensile test specimens. These bars analyzed as follows:

	Grade *A*	Grade *B*
Carbon	0.65	0.69
Chromium	3.62	3.13
Vanadium	0.95	1.68
Tungsten	17.80	13.96

The test specimens were made with shoulders instead of threaded ends, for past experience has shown that it is impossible to obtain accurate tensile test results on hardened high speed steel with the standard U. S. threaded end test pieces, due to the specimens usually failing in the threads.



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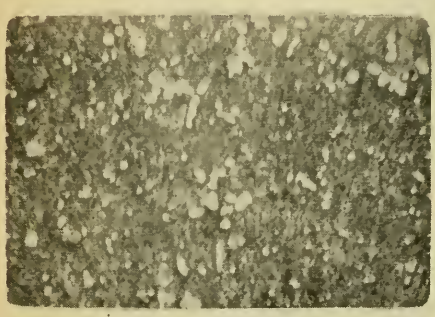

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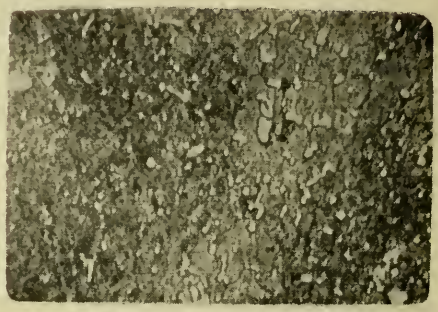

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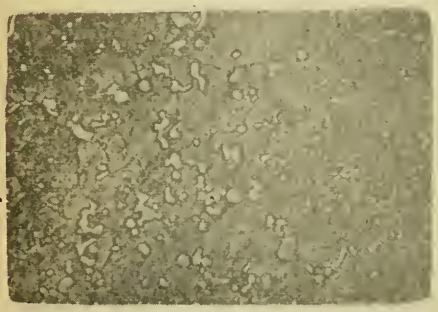

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Figs. 19-24—Micrographs of grade *A* tensile test series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 19.—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at room temperature. Fig. 20—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at 600 degrees Fahr. Fig. 21—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at 1200 degrees Fahr. Fig. 22—Cross section, 2350 degrees Fahr. oil quenched, drawn to 450 degrees Fahr., tested at room temperature. Fig. 23—Cross section, 2350 degrees Fahr. oil quenched, not drawn, tested at 800 degrees Fahr. Fig. 24—Cross section, 2350 degrees Fahr. oil quenched, not drawn, tested at 1100 degrees Fahr.

A large number of these specimens were to be tested at elevated temperatures, so the test specimens were made 11 inches in length in order to allow a sufficient length on each end of the test specimen to extend through the electric heater so as to fit into the specially designed holders. The electric heater, shown in Fig. 31, is quite similar in design to that used by Mr. MacPherran.[1]

Fig. 32 shows the heater in position on the Tinius Olsen universal testing machine. All specimens were held at temperature for 30 minutes before being tested. The results obtained with the various heat treatments, and at the different temperatures tested, are shown in Fig. 33. Additional tensile tests are shown in Table II. The fractures of the grade *A* specimens pulled at room temperature all had the usual velvety appearance, but the fractures of the specimens made from grade *B* steel, all showed a coarse, fairly crystalline structure. The author believes that this coarseness is due not only to the high quenching temperature but also to the fact that the material as received in the annealed condition had large lumps of carbide present, which, of course, would not go into solution upon hardening, as shown in Figs. 18-24. The fractures on the specimens tested at temperatures higher than room temperature presented an interesting range of colors as is shown in the following chart:

Temperature at which specimen was tested degrees Fahr.	Fracture Colors Grade *A* Steel	Grade *B* Steel
Room temperature	Steel gray	Steel gray
400	Steel gray	Steel gray
600	Very dark gray	Very dark gray
800	Chocolate brown	Medium brown
1000	Dark blue	Dark blue
1100	Greenish blue	Greenish blue
1200	Dull purple	Brownish purple

These specimens after being pulled, were also tested with the flat temper testing files, all of these pieces being hard to file with the exception of the grade *A* and *B* specimens tested at 1200 degrees Fahr., these being filed with difficulty, and the grade *A* specimens quenched from 2350 degrees Fahr., not drawn, and tested at 800 degrees Fahr. The specimens which were drawn to 1100 degrees Fahr. before being tested were file hard after each temperature tested from room temperature to 1100 degrees Fahr. This illustrates another advantage of the high drawing treatment, for tools in service which have not been drawn quite often attain a temperature of 600 to 1000 degrees Fahr. These tools, therefore, will be very soft, after being cooled to room temperature in comparison with their original hardness, whereas tools drawn to 1100-1150 degrees Fahr. before being placed into service will maintain their hardness when cooled to room temperature from any temperature up to the original drawing heat.

Micrographs were taken from some of these tensile test specimens and are shown in Figs. 18-30. As stated in a previous part of this article, the microstructure of the grade *B* steel was in a very unfavorable condition as received, due to the presence of large carbide lumps. The structure on the grade *A* material as received, is satisfactory. Specimens drawn to 1100 degrees Fahr. after quenching show the same microstructure after

1 "Comparative Tests of Steel at High Temperatures," by R. S. MacPherran, A. S. T. M. Proceedings, 1921.

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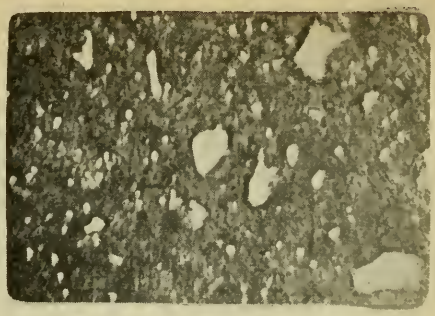

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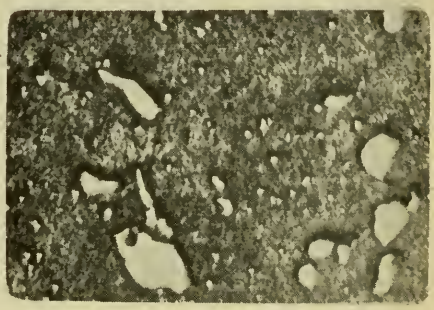

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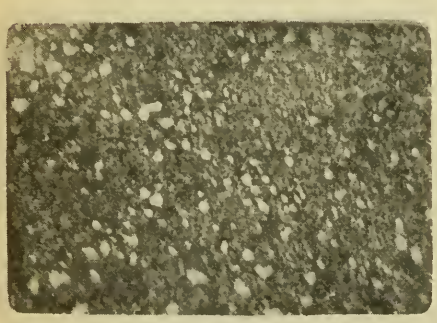

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Figs. 25-30—Micrographs of grade *B* tensile test series. Etched 3 minutes in 5 per cent nital and X 465. Fig. 25—Longitudinal section, annealed condition. Fig. 26—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at room temperature. Fig. 27—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at 600 degrees Fahr. Fig. 28—Cross section, 2350 degrees Fahr. oil quenched, drawn to 1100 degrees Fahr., tested at 1200 degrees Fahr. Fig. 29—Cross section, carbon tool steel. 1440 degrees Fahr. brine quenched, drawn to 400 degrees Fahr., tested at room temperature. Fig. 30—Cross section, carbon tool steel. 1440 degrees Fahr. brine quenched, drawn to 400 degrees Fahr., tested at 1100 degrees Fahr.

every temperature at which the specimen was tested. This is to be expected, for a temperature higher than the original drawing temperature must be exceeded before the martensitic matrix is changed into troostite.

Micrographs of the samples of carbon tool steel tested at room temperature and 1100 degrees Fahr. are also shown in Figs. 25-30. The sample tested at room temperature shows a martensitic matrix with free cementite present, while the samples tested at 1100 degrees Fahr. show a sorbitic matrix with a large amount of free cementite present.

Referring again to Fig. 33, we note that both grades of steel attain their maximum tensile strength at 600 degrees Fahr. Hardened high speed steel, therefore, gives the same characteristic curves when tested at elevated temperatures, as do plain carbon and alloy steels. The grade *B* specimens gave lower reading than the type *A* samples, as would be expected from an examination of the fractures. The author believes that drawing specimens of both grades of steel to 1150-1175 degrees Fahr. would have produced higher tensile strengths, without sacrificing the hardness to any extent.

Grade *A* test specimens quenched from 2350 degrees Fahr. and not drawn showed a tensile strength of only 175,000 pounds to the square inch, about 70 per cent of the value obtained in specimens quenched from 2350 degrees Fahr. and drawn to 1100 degrees Fahr. Specimens drawn to 450 degrees Fahr. after being quenched from the high temperatures, showed a tensile strength of 185,000 pounds to the square inch. Very little increase in strength, therefore, is obtained by drawing to only 450 degrees Fahr. Carbon tool steel, given its usual heat treatment, gave a tensile strength of 183,500 pounds to the square inch, tested at room temperature, and 65,000 pounds to the square inch when tested at 1100 degrees Fahr. Carbon tool steel shows a higher tensile strength at room temperature than high speed steel quenched from 2350 degrees Fahr. and not drawn.

All of the high speed test specimens were measured for elongation and reduction of area and none was obtained, even on samples pulled at the high temperatures. Hardened high speed steel, therefore, possesses zero ductility, even when tested at a red heat.

The following precautions were taken in conducting these tests: (1) The specimens were all timer hardened, so as to insure the heat treatment being a constant; (2) All pyrometers were carefully calibrated before being used; (3) The accuracy of the testing machine was determined.

The writer does not wish to convey the impression that the physical strength of high speed steel is an indication of its cutting qualities, but does believe that tools possessing the proper analysis, hardness, and red hardness, together with the highest possible physical strength, will give the most satisfactory service.

Discussion of Mr. d'Arcambal's Paper

CHAIRMAN FOLEY: Mr. D'Arcambal seemed to find it is very difficult to get respective hardness tests on high speed steel that mean anything. I suppose that is the general experience in testing high speed steel. After all, the real test of that is in the eating of the pudding.

DR. JOHNSON: I would like to ask just with regard to carry-

ing those drawings higher, whether you expect then, no doubt, to get some elongation or reduction in your high speed steel. Did you carry them higher to see what elongation and reduction you could have gotten in high speed steel? This is interesting to me from the fact that we have some such line of work in mind, but have not gotten to it as yet. Suppose you had drawn your tests to 1300 and 1400 degrees Fahr., what then?

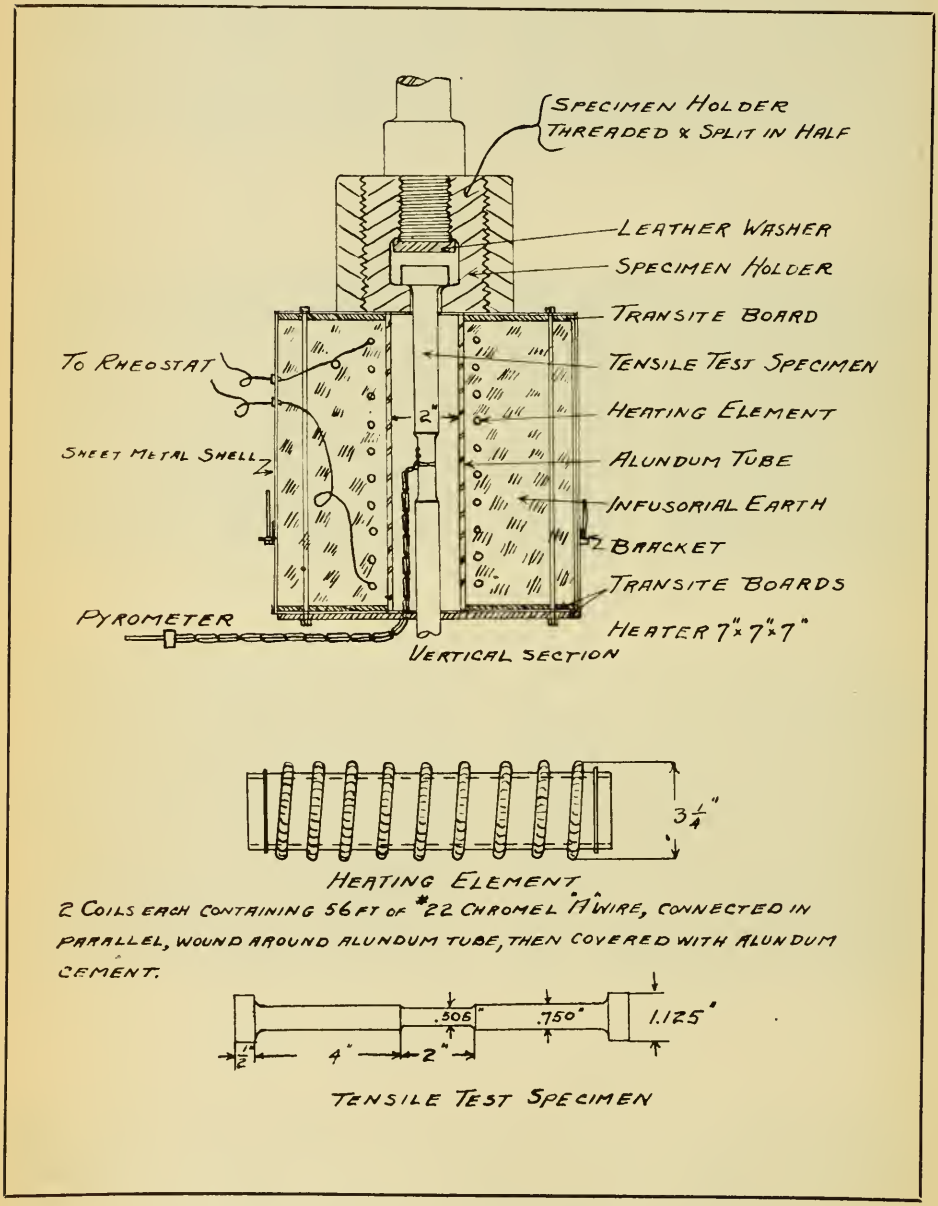

Fig. 31—Cross sectional view of electric heater and test specimen

MR. D'ARCAMBAL: We tested up to 1200 degrees Fahr. only, as we had made up only enough test specimens to cover that range. never expecting to obtain such results as to elongation and reduction. We really expected to obtain some ductility from 1000 degrees Fahr. and higher. Time did not permit of our making and breaking more specimens, but we will try to do so, as I am interested also in seeing just where you do get ductility in hardened high speed steel. I really think if we would have drawn those specimens to 1150 or 1175 degrees Fahr. before testing, we would have obtained higher results on tensile strength. Don't you believe so?

DR. JOHNSON: Possibly so. But those drawing propositions do not, as you know. In some of the higher draws you get results that you don't expect.

MR. D'ARCAMBAL: One thing I omitted stating was regarding the fracture colors. It was interesting to note the colors obtained on the fractures after the specimens were taken from the heater. Testing at room temperature, we obtained the ordinary steel gray, at 400 degrees Fahr. the fractures were still of a steel gray color, testing at 600 degrees Fahr. the fractures were of quite a dark gray, but still there was no noticeable color in the fracture. Testing at 800 degrees Fahr., the fracture on the 18 per cent tungsten steel was chocolate brown color, and the 14 per cent tungsten, 2 per cent vanadium steel the fracture was a medium brown color. Testing at 1000 degrees Fahr., the fracture on the 18 per cent tungsten steel was a dark blue, the same color as we obtained on the 14 per cent tungsten steel. Testing at 1100 degrees Fahr. the fracture on the 18 per cent tungsten was a greenish blue, and the same color obtained on the 14 per cent tungsten. Testing at 1200 degrees Fahr., the color of the fracture on the 18 per cent tungsten was a dull purple, and on the 14 per cent tungsten steel a brownish purple. But I don't believe those colors mean very much, because we found that they depended a lot on the time we left the specimens in the heater after they failed. Unless we removed the specimens immediately, the colors varied.

CHAIRMAN FOLEY: How long did you hold those in the drawing temperature at 1100 degrees Fahr. when you drew them to 450 degrees Fahr., that is where you heat treated the specimens?

MR. D'ARCAMBAL: They were first placed in the oil and brought up to around 500 degrees Fahr., which required, we will say, 35 minutes, then placed in the lead bath at around 700 degrees Fahr. and brought up to 1100 degrees Fahr. and then held there for 15 minutes. One mistake that has been made on the drawing of high speed steel, is to just bring the work up to 1100 degrees Fahr., or whatever it is drawn to, and then to take it out. We have taken high speed steel and quenched it in oil and then drawn to 1100 degrees Fahr. holding there for an hour, and it is absolutely file hard. In other words, you cannot over-draw like you can other types of steel. In pulling the test pieces, it would usually take around half an hour for the pyrometer and the piece to come to temperature. We allowed the specimen to remain at that temperature another half hour and then tested the same. The thermocouple was attached to the specimen, the asbestos cord breaking, as well as some of the porcelain insulators when the specimens failed. Before running these tests we had our

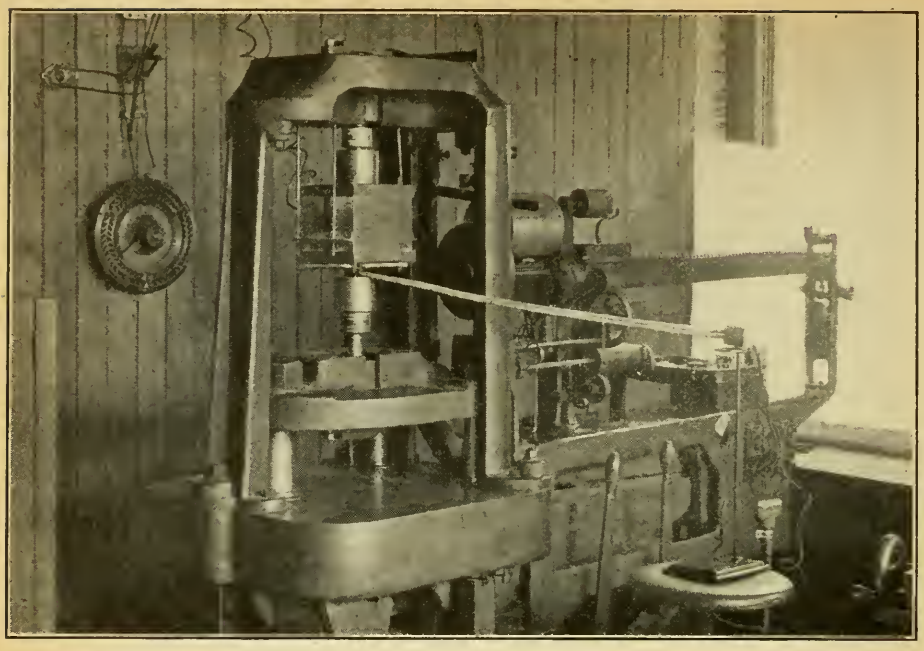

Fig. 32 Electric heater shown in position on testing machine

tensile machine standardized, and we checked all our thermocouples in order to insure the results being accurate.

MR. CROWE: I would like to ask Mr. D'Arcambal if there seems to be any relation between the physical properties in the performance of tools made from steel? Can you pick out steel that has good physical properties?

MR. D'ARCAMBAL: I never tried to do that. I don't want to try to convey the impression that you can pick out a good high speed steel by its strength, that is, a high speed steel having the highest physical strength will make the best cutting tool, but I do believe that high speed tools having the proper analysis, hardness and red hardness, together with the highest possible physical strength, will do the most work. In other words, you can take a high speed steel tool with the proper analysis, quench it and probably give it a long draw. It hasn't the highest possible physical strength, and I believe for that reason on tools drawn to 1100 degrees Fahr. you will obtain greater production because you get greater strength than with the low draw, obtaining therefore, greater life with the high draw.

MR. WEED: I would like to ask Mr. D'Arcambal if he thinks the treatment at 1100 degrees Fahr. draw should be used for all high speed tools, and do away with lower draws.

MR. D'ARCAMBAL: I think so, yes. I have heard some people state that they have tried the high draw and it doesn't work on all kinds of cutting, but I see no reason why it should not. In other words, it insures you of obtaining the proper quenching temperature, for you can take a tool and quench it from 2100 degrees Fahr. and it is file hard without drawing, but a quenching temperature of from

2300 to 2350 degrees Fahr. is necessary to obtain the proper hardness after the high draw. Your high draw will also give you greater stability. One way to prove that is to take a specimen and quench it and then draw to different temperatures and you obtain the characteristic scleroscope or Brinell curve. It will go straight, then down, and at 1000 degrees Fahr. you start coming up again. You take the specimen again, after it has had the 1100 degree Fahr. draw, and draw it again through those temperatures, and you have a straight line, about 92 scleroscope all the way through. The high draw on any tool will give you the greatest possible physical strength and also thermal stability. I cannot imagine any tool, where the high draw will not be beneficial, unless it is a special type of tool that wants to be soft. In that case, possibly it is better to draw to 500 degrees Fahr. Of course, you take some form cutters, threaded tools, etc., and it is a mighty hard proposition to quench from 2300 degrees Fahr. and not spoil your tool on account of excessive scaling. So a lot of people pack harden form cutters and say they obtain wonderful results. The reason for that is that the usual type of form cutters are run at low speeds, probably the regular carbon steel speeds.

MR. GROSSMAN: I would like to ask Mr. D'Arcambal what the concordance of the transverse tests were?

MR. D'ARCAMBAL: Transverse tests checked quite closely. I would say both the transverse and tensile tests checked within 2 to 4 per cent, possibly around 2 per cent. On the transverse tests, some

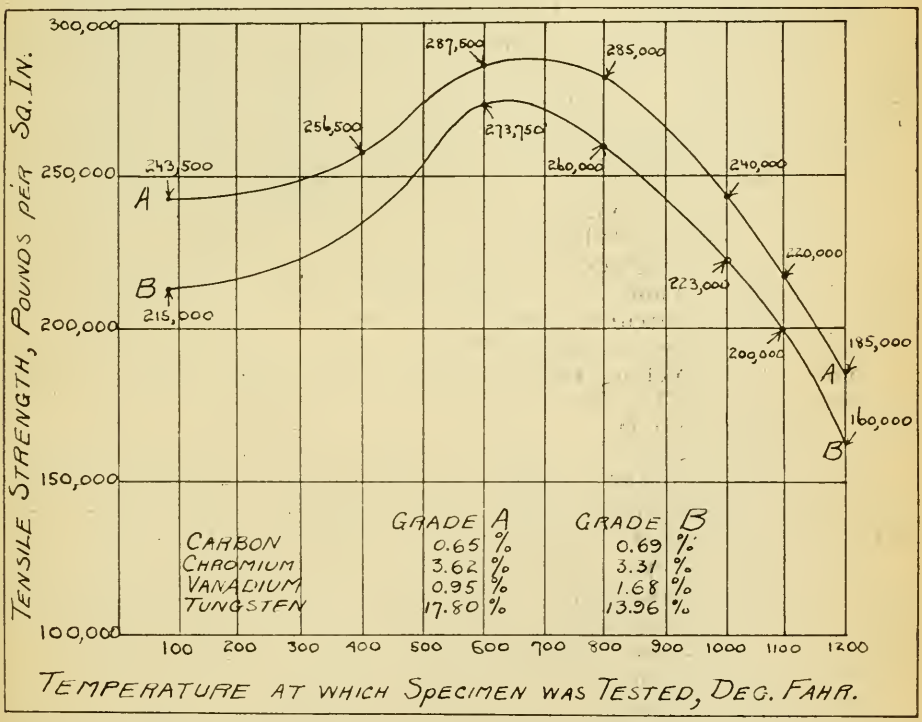

Fig. 33—Tensile test curves. All of the specimens were quenched in oil from 2350 degrees Fahr. and drawn to 1100 degrees Fahr. before being tested

samples we ran in triplicate. On the tensile tests we only run them in duplicate. I was a little afraid at first that the results wouldn't check very closely, but was quite surprised to note how closely they did check. I think one reason for that is that the specimens in each case were all made from the same bar of steel. That insured the same chemical composition and manufacturing conditions. They were all machined at the same time, kept in the high temperature furnace the same length of time, quenched in the same way and all drawn at the same time. I think for that reason the results agreed fairly accurately.

MR. GILLETTE: I would like to ask a question with regard to that curve. In drawing you state that the first drawnig that you get a drop in your curve and then if you draw the same specimen again that you get a straight line. Is that always proved true?

MR. D'ARCAMBAL: I have checked that about four times with different specimens, and have obtained the same results. Quenching and not drawing you obtain a scleroscope of about 92. Drawing to 600 degrees Fahr., it goes down to 86 or 87; at 800 or 900 degrees Fahr. it remains about the same. Say you did have a 93 at 1100 degrees Fahr. draw, you start over again and draw and you get 93 at each drawing temperature, obtaining a straight line the second time. The file also verifies that.

MR. GILLETTE: What would be the result if you requenched that? Would it go through the same line and would the curves compare?

MR. D'ARCAMBAL: What temperature?

MR. GILLETTE: As I understand your statements, if you get a high enough temperature for your original quench, your drawing operations will show a different curve. For instance, we will say 2300 or 2250 degrees Fahr. As I understand it the lower heat on the initial quenching will not give you the same curve as the higher heat will.

MR. D'ARCAMBAL: No, it will not. It will give you the same initial hardness. Drawing to 600 and 800 degrees Fahr. you would get the same results. Where you get the difference is when you get up to 1050 or 1100 degrees Fahr. You can take a specimen you quench from 2350 degrees Fahr. and you can go up to about 1200 degrees Fahr. before you get a softening. At 1200 degrees Fahr. you will still have about 93 scleroscope. Your softening comes at a higher temperature, the higher the quenching temperature.

MR. GILLETTE: Then according to my understanding, you get the drop at around 600 or 700 degrees Fahr. regardless of what your initial quenching is.

MR. D'ARCAMBAL: I have tried that on specimens quenched from 2100 degrees Fahr. heated in a barium bath, and on specimens quenched from 2300 degrees Fahr., and on all we obtained about the same initial scleroscope, and falling off at 600-800 degrees Fahr.

MR. EDWARDS: On a big lathe tool it has been found sometimes to be just as good if it wasn't drawn at all as where it was drawn to 1100 degrees Fahr. Is that because the heat is generated so fast that it comes up to 1100 degrees Fahr. so rapidly there is no chance for it to get away before it gets up there?

MR. D'ARCAMBAL: I think that is exactly the case. A good many lathe tools run continuously at a dull red heat. Professor Arnold in England tested some hardened but undrawn lathe tools and dis-

covered that always on the first re-grind they ran better. The fact is that on the first running he drew them. Then on the second trial he got better results. Try to get a blacksmith to draw a high speed tool to 1100 degrees Fahr. and he would think you had had a drink of "hooch."

QUESTION: If you had a point of 350 degrees Fahr. and then drawing up to 500 degrees, and then running up to 1100 or 1150 degrees and leaving your tool in the lead, letting it freeze there, then bringing it back, after it is perfectly cold to the 1100 degrees of heat again, what would be the result?

MR. D'ARCAMBAL: The same result as though you took it out of the lead; it would be the same thing as running it in practice afterwards and getting it heated up, then cooling off.

DR. JOHNSON: I notice the speaker quotes scleroscope readings there along with the different drawings with a percentage of accuracy. Now what percentage of accuracy does he think he got in the scleroscope readings?

MR. D'ARCAMBAL: In order to obtain the greatest accuracy on scleroscope testing, we had specimens surface ground after hardening, taking about 0.020 inch off of each face. Then we scleroscoped each of the ground surfaces, about 10 readings on each face, making 20 readings on the piece, and then averaged them, and you have some variation, even at that. You take the test blocks that the instrument company furnishes, supposed to read 103, you put it on the base of the machine and read it and it is 103, put a very thin piece of paper on it under the block and you get about 90. If you don't have absolutely parallel surfaces it is not worth anything. That is the reason I don't believe the scleroscope or Brinell is worth much on testing tools.

MR. NELSON: Mr. D'Arcambal referred to experiments carried on in England by Professor Arnold. I have been present at quite a lot of those tests of Professor Arnold and I think it is only fair to Mr. D'Arcambal to say that those tests made by Professor Arnold support his own paper as given here.

THE PRESENT SITUATION FROM A BUSINESS STANDPOINT

By Richard Spillane

I CANNOT indulge in technical language; I speak only ordinary United States. In fact, my province is not speaking, I just do a bit of word carpentry in the written form, but I have pronounced ideas about various subjects and one of them is that we have not looked at some of the influences of our present development. I believe we might have had aggravated trouble a little later, if it had not been for the war. We have had in the last 100 or 150 years the greatest revolutions in the history of the world. We know our historical resumes place Alexander, Caesar, Charlemagne, Napoleon and probably the Kaiser as the great revolutionists of the world. They were really pikers; the real revolutionists of the world have been Watt, Stevenson, Hargreaves, Eli Whitney, Morse, Edison and Marconi. These men changed this world of ours from a dreary to an industrial world. They wrought greater changes in the last 150 years than in all the preceding ages. Those of you who have read know that before the age of steam, the work shop or factory, whatever you wish to call it, was in the home. They did not have a distributing agency. It was not until they began to manufacture cotton goods with the loom and spindle, that there was a necessity for a real distributing system and we do not pay attention today, do not recognize today the wonderful changes that have come to us.

A talk that was printed this morning shows a resume from a revision by Mr. MacFarlane in Commercial America. In 1921, imports of machinery into India had a value of $68,000,000. This was more than twice the value of all the machinery exports of Great Britain and the United States in 1870.

In 1920, imports of machinery into China were $29,802,000, or nearly as much as the total machinery exports of Great Britain and the United States to all countries in 1870. The tremendous industrial development throughout the world in the last 50 years, the change from agrarianism to industrialism, explains to a large degree how the world war dislocated every geographical division. Dependence upon machine power has greatly increased the interdependence of nations.

Up to 1870 Great Britain virtually dominated the machine market; in that year her exports of machinery were $25,000,000, and those of the United States $5,000,000. In 1920 the exports of the United Kingdom had reached $308,000,000, or 12 times those of 1870, while those of the United States had vaulted up to $536,000,000, or 107 times greater than in 1870. Today the total machinery exports of the principal nations aggregate more than a billion dollars with the United States commanding more than one-half of the total and apparently being destined to increase her leadership. I may tell you the exports of sewing machines alone from the United States in one year now are three times greater than all of our machinery exports in 1870; exports of typewriters are five times as great as all of our machinery exports in 1870. The same thing is true in relation to adding machines, so when you come to automobiles, you have to express it in very fine terms.

The war you may trace, in part, to the impetuosity of the Germans.

A paper presented before the Philadelphia Chapter. The author, Richard Spillane, is editor business section, *Philadelphia Public Ledger*.

They wanted to get to the front at a quicker pace than they would otherwise reach that goal. What I would like to point out is this, that with this tremendous change in 50 years for the drawing together of the world, what can we expect in exports 25 or 50 years hence? If you can make such an advance in infancy, what can you expect as you approach maturity?

With this tremendous revolution, we have brought about various troubles. We have gone into production in this country on the most gigantic scale ever known and we have arranged all of our methods of production for the maximum production and while we have been doing so, we have paid little attention to another cog in the whole machine—that of distribution. Today we are between the devil and the deep blue sea with the tremendous costs of our distribution. If you take $10.00 as a unit of cost for a product of the General Electric Co., this being amount paid by the consumer, the amount received by the General Electric Co. for that product would be $2.59. These are not my figures, but figures obtained from the General Electric Co. I would like to know why for what they sell for $2.59, the consumer should pay $10.00?

I give as another illustration the soda cracker. When I was a youth, I went to the grocery store and I used to have a free lunch. I could go to the soda cracker barrel and get as many as my stomach would hold or that my appetite would crave and soda crackers in those days cost 5 cents per pound. It was not a very sanitary way for everybody went to the barrel and some people were not as sanitary as possible. I live out in the country now and a short time ago my wife requested me to bring home some saltines. Saltines, as I know them, are soda crackers with a little salt on them. I bought a box of saltines all put up in a nice box, neatly and sanitarily packed in an attractive container. I paid 18 cents for the container of saltines. I put them on the scale, resulting in the information that a pound of soda crackers, at the price I paid for these saltines, would today be 78 cents. If anybody on earth can justify an increase from 5 to 78 cents for soda crackers, just on account of their being put up in a little bit more sanitary method and in a more attractive container, I cannot see it.

You have the same thing in many different forms in this country. I was present at a banquet at the Bellevue Stratford one night recently and they had present some of the most eminent bankers of this district, also eminent engineers. The bankers confessed they were up a tree in many ways. They said this matter of distribution was hog-tying the industry of the country, and the engineer was greatly responsible—he was a person with an undetached mind. Some of their statements were that the engineer had been responsible for the development of the machine and it was now up to him to work out this problem of distribution. I think they are right. The engineer has an undetached mind. We have to settle this cost of distribution. It is one of the most horrible wastes we have in this country. It is in every field and every form. Take for example the matter of your own steel industry. I sat alongside of Charles M. Schwab the other night and after the regular speakers, the crowd called for Mr. Schwab. After telling a few pleasant stories, Mr. Schwab made a remark that at Bethlehem they were not making any money; that they had to sell steel at less than cost, also that the cost of the five elements necessary to the making of steel, plus the freight rate was more today than the price they got for steel, but

that really one of the largest costs was transportation. He asked some of the railroad executives who were present, to take that home with them.

It is one of the problems. You can recall when we rode around this country for 2 cents a mile—you cannot do that today. I rode about 8000 miles recently and I got a little information on the road and more jolts, principally down in the southwest. I will never forget the trip from New Orleans to Dallas—I thought I was going through the roof of the sleeper at times. Some of the prices I had to pay for transportation put an awful kink in my bank roll. The railroads do not seem to be making money. They have to pay a large amount of money for things they have to purchase. They cannot rehabilitate themselves. They have need for steel to a degree they never knew before; needs for lumber; needs for everything. One of the railroad presidents that I interviewed on my trip, almost wept on my shoulder, telling me the sad experiences he had to undergo. One thing was that the month previous he did not know whether he was going to be able to meet his payroll and had drawn on the banks to the limit. Somehow he bridged the situation.

I also met a number of steel people. I met the executives of the United States Steel Corp.; the Colorado Fuel & Iron Co.; and Tennessee Coal, Iron & Railroad Co. From some of them I got remarkable statements. Mr. Crawford, of the Tennessee Coal, Iron & Railroad Co., told me that he had offered to supply the rails urgently needed by one of the railroads of the South and the president of the road declined his offer to furnish the steel and wait for payment, because he had to reduce his maintenance of way force to such a degree that he did not have sufficient men to take out the old rails and put in the new. That condition is, to a great extent, applicable to every part of the country. They should place orders now, but the railroads, from reports of railroad presidents made to me, never were in such urgent need of refurnishing, particularly as to steel.

I do not know whether you gentlemen will coincide with my views. I do not think that Europe, for instance, is in so bad a condition of financial bankruptcy, as she is in bankruptcy of brains. We are going to have some of the governments abroad, some of the nations abroad go bankrupt—the quicker they do so, the better for them and the better for the world. Bankruptcy of a nation is not what bankruptcy is to a business concern. You cannot take from a nation the real assets; you cannot take from it the earth and human power; you cannot take from it the growth of crops, for men will work when it comes down to live or die.

We have had some practical knowledge of the debasement of money. You get debasement of money abroad to a degree that is appalling, but you know we are a thoughtless lot. We do not look back to the debasement of the currency of the United States. We do not remember that we had some horrible situation to meet in these United States and we do not appreciate how stupid we have been ourselves at times.

One of the noblest works of men, to my mind, is the constitution of the United States. Some eminent foreigners have told us there is nothing that has come from the pen of man, in the last 18 to 20 centuries comparable to it. It took the leading men of the United States about six months to agree upon the framing of the constitution and it took more than six months after it was framed for the people of the United States

to accept it. In the great state of New York they held a convention at Poughkeepsie; De Witt Clinton led one faction, Alexander Hamilton the other. De Witt Clinton and his following had about three-fourths of the convention—Mr. Hamilton but a very small part. It was not until after the required number of states had accepted the constitution that New York accepted the document which is now the constitution of the United States. During that time, the dollar that we know today, was debased to the point, where it had the purchasing power of only 2 cents. Our whole commerce was at a standstill. There were very few ships on the sea with the American flag; we had no industry, no business. We were about in the condition that parts of Russia are in today. We do not remember these things, but as soon as we got started, we got back in a short time.

We have had bankruptcy of nations in various parts of the world; there have been several occurrences in South America; Argentine went bankrupt twice; France did some crazy things in finance. Then we have Poland before us now. Mr. Vanderlip says that when he was in Warsaw a few months ago, he stopped on the street to look at a woman selling newspapers. She had by her side a pile of newspapers unsold (we do not blame anybody for not buying a Polish newspaper). Alongside of the newspapers she had a stack of paper money and the stack of paper money was almost as large as the stack of newspapers and of almost the same value. He also tells of when in Vienna, he hired a taxicab and rode about that beautiful city for an hour or so. When he came to pay his score, he paid the meter price 60 times over and found when he translated the money into gold equivalent, it would have been cheaper for him to keep the cab all day than to hire another. In Berlin he rode about for a considerable time in a taxi and that time paid the taxi only six times the registered fee and in gold equivalent he had paid out 4 cents. The sooner they get rid of this paper blockade in Europe the better. They have got to get rid of a lot of other things. One thing they must get rid of is their passion for hate; they have also got to get rid of their present method of hitting at each other's geographical lines.

Senator Hitchcock, of Nebraska, wants to establish a Bank of Nations, a Federal Reserve of Nations. Of course, the United States is to hold the bank; capital to be $2,400,000,000. Mr. Vanderlip has a little different scheme. Senator Hitchcock was for the United States to control this money. Some of our friends, particularly the British, who have a genius for finance, would not quite agree with this proposition. Mr. Vanderlip has another idea, he would also have a Federal Reserve Bank of United States of Europe and it would be for us to put up the money holding on to it until they got out of their quagmire abroad, then they would resume control and we would gracefully retire. He also thinks that Europe ought to pay the debt it owes to us. We are all strong for that. Mr. Vanderlip does not think that it ought to be paid now, in 10 years or 25 years, but that they ought to pay that money to us and we should hold on to it for about two and one-half minutes, then we should employ it to the great work necessary abroad for the transportation system, etc., particularly the hydroelectric development. He believes there would be a very good profit in 25 years, or more, then Europe could repay that money.

To get down to the real matter, the whole question of the world is individual. It is a matter of work. We all have to work a little harder —we all have to make a bit better return for what we get. We have

done some crazy things every way; we have done a lot of them for which we should be ashamed. We are not justified in many instances to criticize the people of Europe as we do. We have not had the struggle they have had. We have to be generous; we have to be considerate. We have to abate some of the desires for the repayment of the loans we have made abroad. I think that we have assurety of a quicker return to normal conditions in Europe than appears on the surface today. I have great faith in the wish of man to live. When men have to work to live they will get down to brass tacks.

I have great faith when I read about the development of the other continents; when you think of what Asia has to develop. In the next 50 years, they will astound the world; their resources are beyond belief. There is more coal in China than in the United States and we have a lot of it here. The State of Colorado has equally as much as this wonderful land of Pennsylvania and I think Utah has more than there is in Colorado. China has more iron ore than we have. She has illimitable resources, if we are to believe the records of the geological survey people. We are getting down to the beginning of real industry in the Far East. We know nothing of the real worth of Africa; the copper deposits of Africa are immeasurable; these are about 2000 miles inland and until that country is opened up, no one knows what the developments will be in that section as well as South Africa.

The same is true with South America. I have talked with Mr. Braden, one of the greatest copper men in the world. He now controls in Southern Bolivia, in South Argentine and West Argentine, the foot hills of the Andes, 25 million acres of land that the geological people declare is very profuse with oil. They declare that the largest oil field that the world knows is in Southern Bolivia. I have read reports of 28 different surveys made by men eminent in the field of oil and they all report very fine oil territory in the Andes. The same way in North and South Argentine, Venezuela, Colombia, and Northern Brazil.

With the opening up of the South American oil fields, as they will be opened up, I may tell you that the Braden proposition is for the deepening of various rivers leading into the territory of Southern Bolivia. We should procure a passage for ocean steamers to go about 1200 miles up from Buenos Ayres. This will be a wonderful revision in transportation in the Southern Seas. There will be a development in the south comparable to something like the north and with all this, what is it going to do for your line. If the exports of machinery today amount to one billion dollars and it sprang from 30 to 35 million in 1870, what can you expect in 1970—50 years hence, 25 years hence? I think any man can make a guess and it may seem wild, yet it may be reasonable. This world we look upon is fairly well developed, but it is only in its swaddling clothes. This development is due to the industrial leader today who is the steel man. If he is not, I would like to know who is.

DOWMETAL AND ITS APPLICATIONS

By J. A. Gann

METALLIC magnesium is the lightest known metal that can be classed as an engineering material, and it has only recently received this distinction. This metal has been used in the past chiefly as a deoxidizer, for photographic flashlights, for pyrotechnics and explosives, and in alloys where small amounts are often desirable. The annual consumption for all these purposes prior to the war probably did not exceed 35,000 to 40,000 pounds and almost the entire supply came from Germany. When importations were cut off in 1915, large scale domestic production of magnesium was started in order to meet the demand for military purposes, and by 1918 the estimated output reached 400,000 pounds. This industry proved to be chiefly a war-baby as evidenced by the fact that in 1919 production in most plants practically had ceased. In anticipation of such a condition, the Dow Chemical Co., Midland, Mich., started investigations as far back as 1916, the object being to develop a metal adapted to peacetime industries. The series of magnesium alloys commercially known as dowmetal is the result.

The Dow Chemical Co. is situated advantageously as far as the magnesium industry is concerned. The main source of raw material for its various plants is a brine pumped from a depth of 1200 to 1400 feet; and magnesium chloride, one of the salts contained in this brine, is the chief raw material used in the production of the metal. This salt must first be dehydrated to remove its water of crystallization, after which it is fused and electrolyzed. The extreme lightness of the magnesium thus formed is at once apparent as it is found floating on the surface of the molten bath. After refining, the metal analyzes as high as 99.0 to 99.5 per cent pure, with magnesium oxide, iron and carbon as the chief impurities.

In developing commercial uses of magnesium, cognizance necessarily must be taken of its more important chemical and physical properties. Largely because of its lightness and the effect this would have on the reciprocating parts of an engine, its use as a piston material was early suggested and when preliminary tests indicated great possibilities all energy was devoted to this field. While the physical properties of commercially pure magnesium are such as to recommend it for certain purposes, many of them can be improved materially by alloying it properly with small quantities of other metals. This is especially true in the selection of a piston material, although pistons made from pure magnesium have also proven quite satisfactory. A rapid survey of the field indicated that some of the more desirable combinations of physical properties are found in the magnesium-aluminum series and since they may be considered as typical representatives of dowmetal alloys, and at the same time indicate their range of adaptability, they will be studied more in detail.

Fig. 1 shows the variation in some of the more important physical properties of these alloys produced by adding increasing amounts of aluminum. Those curves designated by H. T. refer to metal heat treated for 2 hours at 800 degrees Fahr., the others to test pieces as cast. The rapid rise in strength with small amounts of aluminum is at once apparent, and if we con-

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A paper presented at the Indianapolis Convention. The author, J. A. Gann, is connected with the physical and metallurgical research laboratory, Dow Chemical Co., Midland, Mich.

fine our attention to the original castings, we find that in most properties the maximum strength is reached when the alloy contains about 6 per cent aluminum. On the addition of still more aluminum, the tensile and transverse strength rapidly decrease while the compressive strength remains practically constant. The per cent elongation and per cent reduction in area curves have been purposely omitted in order to avoid possible confusion as they would cut the other curves several times. They both begin at about 5 per cent for pure magnesium, rise rapidly to 8 to 10 per cent at an aluminum content of 4 per cent, and gradually decrease to 1 per cent at 12 per cent aluminum. The Brinell hardness is roughly proportional to the aluminum content, varying from 35 to 40 for pure magnesium content, varying from 35 to 40 for pure magnesium up to 140 to 150 for a 70 per cent magnesium, 30 per cent aluminum alloy.

The stress-strain diagrams of these alloys are similar to those of other light alloys. They are characterized by their low proportional limit and the absence of any well defined elastic limit and yield point. The curve marked "Load 0.5 per cent elongation" is empirical and represents the load in pounds per square inch required to give an elongation of 0.5 per cent on a 2-inch length. Because of the large number of alloys to be tested, it was desirable to find some value easily obtained that was proportional to the elastic limit and thus save the necessity of determining the stress-strain diagrams for all alloys. Experiments showed that the average elastic limit corresponded closely to this arbitrarily chosen load and in view of the fact that such elastic limit determinations are at best subject to considerable variation and error, the simpler but more exact load at 0.5 per cent elongation was adopted as a standard determination. Such a policy is all the more allowable because of the parallelism between this value and that of the proportional limit.

The increase in strength occasioned by heat treatment depends on the per cent aluminum present. With low aluminum content the strength is practically unaltered, but as more aluminum is added the effect produced becomes more and more pronounced. the maximum occurring at 8 to 12 per cent aluminum. Not only does heat treating increase the strength of the alloy, but it likewise shifts the position of the maximum strength toward alloys with a higher aluminum content. The proportional limit and load at 0.5 per cent elongation curves are not appreciably altered by this process. The per cent elongation curve is the same as for the original castings up to 2 per cent aluminum, and then follows the same tendency as the other heat treated curves to shift the maximum, while the Brinell hardness is slightly lowered. The explanation of these changes as well as the mechanism of heat treatment can be discussed best a little later.

The real value of dowmetal and some of its outstanding advantages are shown in Table I. The values given are either the averages of the most reliable published data or experimental data obtained in our own laboratories. The most outstanding properties are the high strength and low specific gravity. The engineering world has been anxiously searching for just this combination of properties, but heretofore the term "light alloy" has been applied to various alloys of aluminum with specific gravities ranging from 2.65 to 3.00. In dowmetal, however, we have an alloy that is decidedly lighter and whose gravity is only 1.8. Aluminum alloys average 60 per cent heavier, cast iron is four times and red brass almost five times as heavy. The full significance of this combination of strength and light-

ness becomes apparent when we calculate the specific tenacity or the strength per unit weight of metal. We then find that dowmetal is twice as strong as the ordinary aluminum casting alloys, five and one-half times as strong as cast iron and approximately twice as strong as mild steel.

Furthermore, the tensile strength does not decrease rapidly with moderate temperature rises, a property common to so many types of alloys. Repeated experiments have shown that there is no appreciable decrease in strength up to about 400 degrees Fahr., after which it falls off at the rate of 4000 pounds per 100 degrees Fahr. additional temperature rise. Duralumin with its 60,000 to 65,000 pounds per square inch tensile strength is two

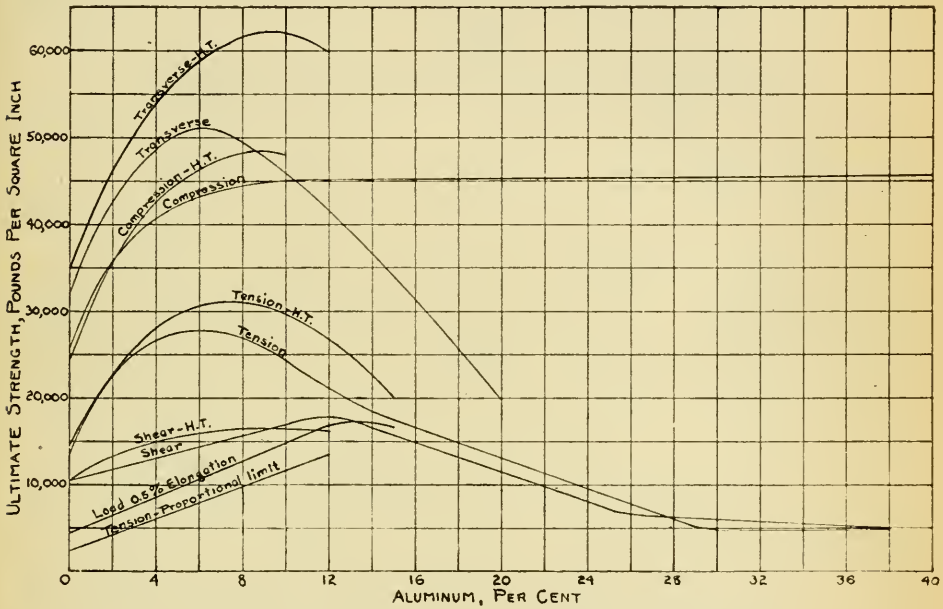


Fig. 1—Physical properties of magnesium-aluminum alloys

and one-half times as strong as dowmetal at room temperature, but is weaker at 600 degrees Fahr. This ability to retain its original strength at temperatures considerably above normal appears to be characteristic of this type of alloy although the temperature at which the break occurs varies somewhat with the composition.

Toughness is a property that is receiving more and more attention. It is now recognized that in many fields, dynamic rather than static tests give the better measure of a metal's adaptability and usefulness. When judged by the single-blow notched-bar impact test, dowmetal "A" is again shows better characteristics than aluminum casting alloys and cast iron, the relative value for these three metals being 45, 20 and 24 respectively. These figures do not represent absolute foot-pounds of energy absorbed per square inch cross section of sample, but simply indicate the relative toughness. This same fact is still more vividly illustrated by throwing on a stone floor articles such as pistons cast from these three metals, by hitting them with a sledge hammer, or by squeezing them in a vise.

Preliminary tests indicate that there is probably a direct relationship

between the single-blow impact test and the fatigue-endurance so long as we are dealing with alloys of a single type such as the magnesium-aluminum series. All comparison ceases, however, when we consider alloys with different types of structure, as illustrated by two alloys with impact numbers of 26 and 18 that withstood 200,000 and 23,840,000 reversals respectively when tested under the same maximum fiber stress.

The most recently published equilibrium diagram of the magnesium-aluminum alloys is given in Fig. 2. This work of Hansan and Gayler confirms the older results of Grube in most respects. The main points of difference are the appearance of a second small maximum at *C* corresponding to the compound Al_3Mg_2 and the claim that the compound formed at the

Table I

Comparative Physical Properties of Sand Cast Metal

Physical Property	Magnesium	Dowmetal "A"	Aluminum Alloy	Aluminum No. 12	Cast Iron
Tensile strength, pounds per square inch..	14,200	25,000	13,000	20,000	18,000
Specific gravity....	1.7	1.8	2.7	2.9	7.2
Specific tenacity, pounds per square inch.....	8,300	14,000	4,800	7,000	2,500
Elongation, per cent	5	4	25	2	Negligible
Compressive strength pounds per square inch.....	24,000	44,000	.....	.....	100,000
Thermal conductivity 20—350 degrees Cent.....	0.375	0.200	0.475	0.391	0.147
Thermal expansion, 20—400 degrees Cent.....	$(0.29x10)^{4}$	$(0.29x10)^{-4}$	$(0.25x10)^{-4}$	$(0.25x10)^{-4}$	$(0.11x10)^{-4}$
Brinell Hardness...	40	55	26	60	125
Melting point, Degrees Cent....	651	615	658	625	1,100

rounded maximum *E* is Al_2Mg_3 and not Al_3Mg_4. Still more important, however, are the positions of the solidus lines *AH* and *GK*, which indicates the ranges of solid solution. In Grube's diagram the lines *AH* and *GK* coincided with the temperature axes and so excluded the formation of any solid solution. The present diagram, however, states that each metal is capable of dissolving about 10 per cent of the other. No attempt has been made to check this value, but the photomicrographs that follow prove that magnesium can hold at least 8 per cent aluminum in solid solution. The question of the number of compounds formed between the two metals and their composition is not of importance here. The physical properties of the alloys in which we are now interested, that is, of the magnesium alloys containing small percentages of aluminum, are chiefly determined by the positions of the eutetic point *F* and the solidus line *GK*, and by the properties of the compound Al_2Mg_3, of magnesium, and of the solid solution of aluminum in magnesium. Both magnesium and the solid solution of aluminum in magnesium are soft but tough and strong. The compound on the other hand is hard, weak, and brittle. By properly regulating the proportion of eutectic to ground mass we can control the physical properties within certain limits.

Fig. 3 shows the microstructure of commercially pure magnesium mag-

nified 200 diameters. We have here the typical structure of a pure metal composed of irregularly shaped polyhedral grains. A considerably lower magnification would be better in this instance and possibly in the lower per cent aluminum alloys, but it is more desirable to keep the magnification constant so as to convey a more accurate impression of the decrease in grain size as the aluminum content is increased.

Fig. 4 shows the structure of a 2 per cent aluminum alloy. The few dark spots represent eutectic, although it was previously stated that magnesium can hold 10 per cent aluminum in solid solution. The castings have cooled so rapidly that there was not sufficient time for complete equilibrium to be established, as the solution of aluminum in magnesium is largely a time factor. A 4 per cent aluminum alloy is shown in Fig. 5. We now find more small globules of eutectic and furthermore find numerous instances where these globules are joined together into a branched chain-like structure. Fig. 6 shows a 6 per cent aluminum alloy in which the chain-like structure is now well developed. It should be remembered that this is the composition at which the maximum in the tensile strength curve occurred. An occasional crystal boundary line is still visible, indicating that the eutectic does not yet dominate the properties of the alloy.

Dowmetal "A", physical properties for which are given in Table I, is an 8 per cent aluminum alloy. As illustrated by Fig. 7 the eutectic is now beginning to surround the magnesium crystals and Fig. 1 tells us that at the same time the tensile strength is beginning to fall off. This slight decrease in tensile strength, however, is more than offset by the corresponding gain in other properties, especially hardness and rigidity. This alloy possesses an exceptionally good combination of physical properties and in many instances has proven its worth as a casting alloy.

Further additions of aluminum yield increasing amounts of eutectic. This, in turn, results in a gradual decrease in size of the primary magnesium crystals and a more complete enveloping of the same by the eutectic until they finally appear as small islands in a sea of eutectic. This transition is illustrated by the 15 and 20 per cent aluminum alloys shown in Figs. 8 and 9. Fig. 10 shows the well developed eutectic structure in an alloy containing 31 per cent aluminum, which is very close to the true eutectic composition.

Heat treatment of these alloys produces marked changes in their microstructure which can be attributed to an increase in the amount of solid solution at the expense of the eutectic originally present. Since solution in a solid medium is largely a question of diffusion and this, in turn, largely a question of pressure and temperature, we should expect the time required for complete heat treatment or complete solid solution to be a function of the temperautre, and experiments have proven this. For example, in dowmetal "A", complete solid solution is produced in 4 hours at 820 degrees Fahr., while 24 hours are required at 750 degrees Fahr. Higher temperatures unquestionably would shorten this time if we could use them, but we are limited here by the melting point of the eutectic alloy, namely, 824 degrees Fahr. It is essential that the temperature be carefully regulated especially when using the higher temperature. This is easily accomplished with an electric furnace equipped with an automatic temperature control. An electric furnace, manufactured by the Modern Equipment Co., Taunton,

Mass., has given good satisfaction as it will continually maintain a constant temperature of plus or minus 1 to 2 degrees Fahr.

If we heat treat an alloy for different lengths of time and then examine the specimens microscopically, we are able to follow the development of the solid solution structure. This is best shown in an 8 per cent aluminum alloy as we then have considerable eutectic and at the same time are far enough away from the saturation limit to get complete solid solution in a

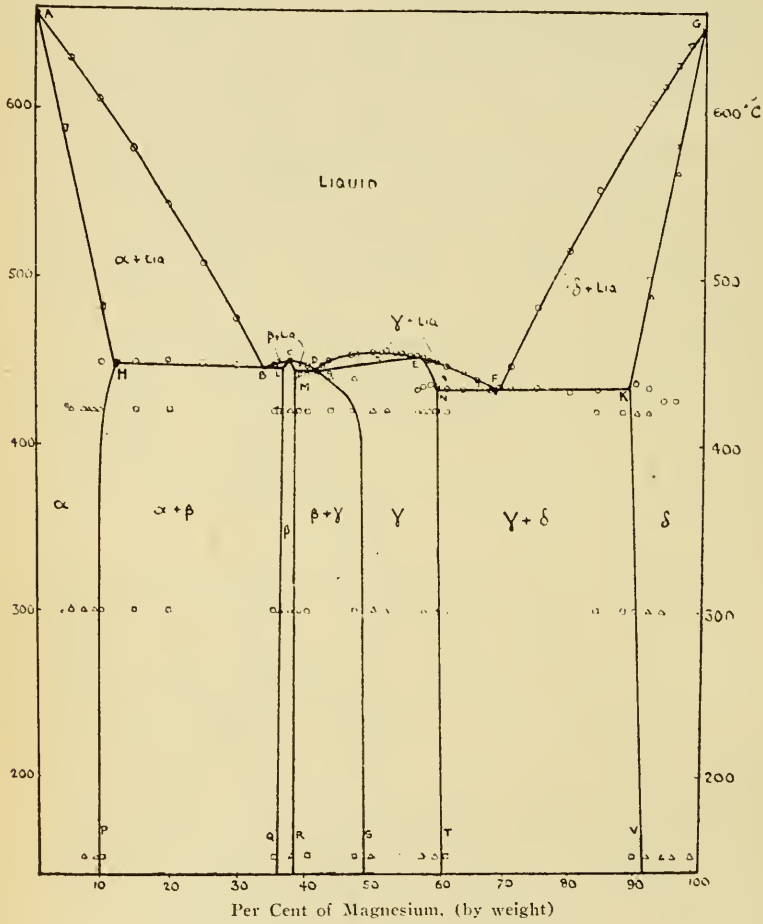


Fig. 2—Magnesium-aluminum equilibrium diagram

reasonable time. Fig. 11 shows the original casting containing the proper amount of eutectic. If this particular alloy be heated for one hour at 820 degrees Fahr., the structure shown in Fig. 12 results. The original chain-like arrangement of the eutectic is beginning to break up, with the result that the large primary crystals are not so completely inclosed by the former. Fig. 13 shows the effect of two hours heating at 820 degrees Fahr. The eutectic has now largely disappeared and the boundary outlines of the solid solution crystal grains are beginning to appear. Four hours at this same temperature gives the well developed solid solution structure repro-

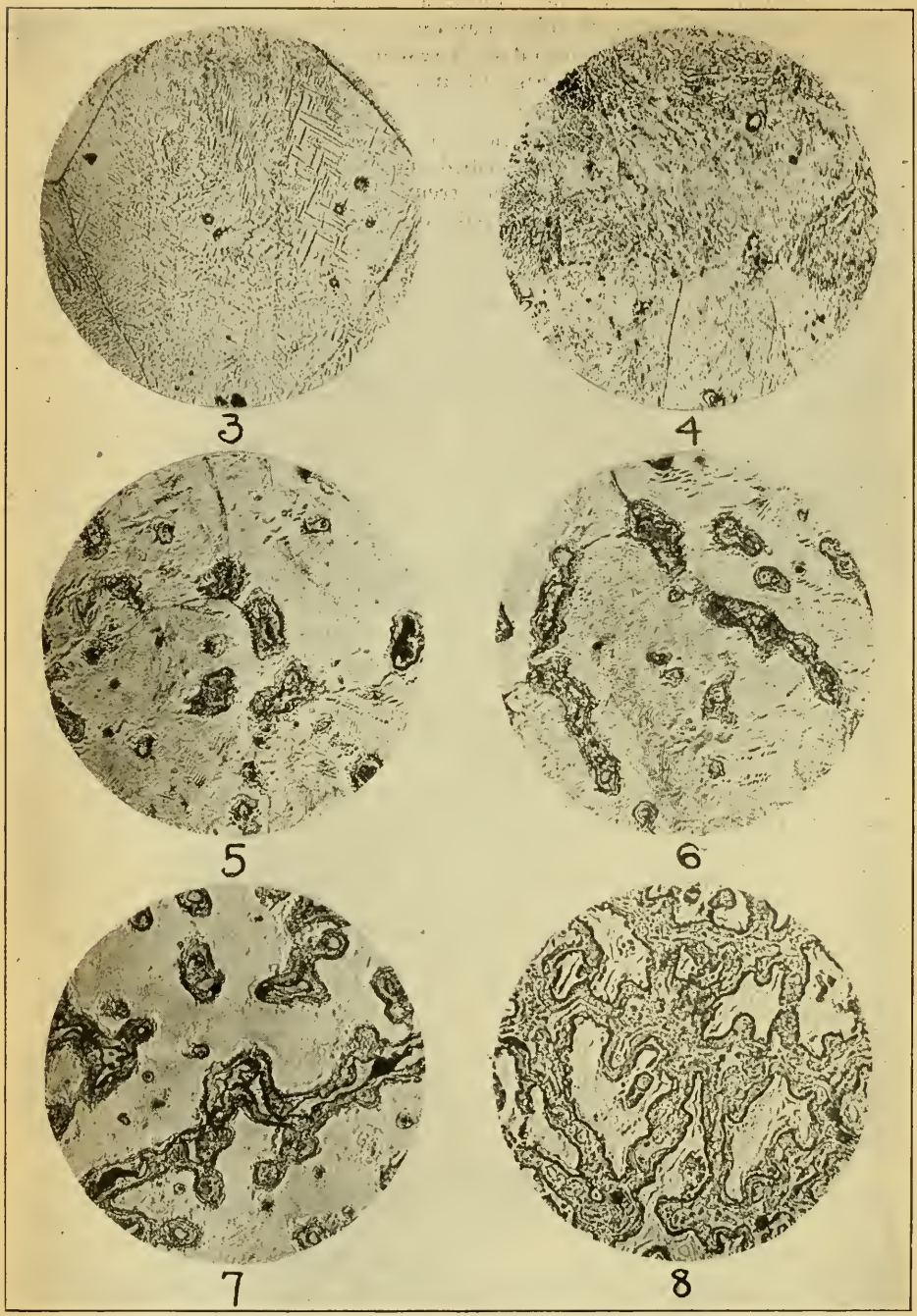
duced in Fig. 14 with only very small amounts of the eutectic visible at the crystal junctions. The maximum increase in strength due to heat treatment occurrs long before complete solid solution is reached. Repeated experiments have shown that this maximum effect is reached when heat treatment has produced the structure shown in Fig. 12 and then remains constant in spite of further changes in microstructure.

The physical property curves now become more intelligible when studied in conjunction with the above described microstructure changes. The function of the eutectic in increasing the strength of the alloy is somewhat comparable to that of steel in reinforced concrete. Exactly the same reasoning explains the increase in Brinell hardness as more and more aluminum is added. It was mentioned previously that magnesium is tough and strong while the eutectic is weak and brittle. If the eutectic is therefore increased to such an extent that it practically surrounds the magnesium, or solid solution, crystals, the strength of the alloy will be governed more and more by that of the eutectic.

A comparison of Figs. 6 and 12 shows a great similarity. Likewise it should be noted that this is the type of structure capable of giving the maximum tensile strength, irrespective of whether it be produced by casting a 6 per cent or by heat treating a still higher per cent aluminum alloy. This leads to the conclusion that the beneficial action of heat treatment is closely related to the breaking up of this enveloping eutectic structure. The lower the per cent aluminum, the fewer the magnesium crystals completely surrounded by eutectic and the smaller the corresponding increase in strength on heat treating. Similarly, in higher per cent aluminum alloys more magnesium crystals are inclosed and the greater the effect of heat treatment. The strength of heat treated specimens continues to rise with increasing aluminum content until the amount of enveloping eutectic is in excess of that which can be broken up by this process.

It has been mentioned previously that dowmetal is now being advocated chiefly as a piston material. The question which then arises naturally is just what are the advantages of dowmetal over those of cast iron and aluminum alloys. The exact physical properties that are actually required in a satisfactory piston material is more or less an open question among automotive engineers. The problem is still further complicated by the fact that variations in certain properties of the different metals can be overcome by alterations in piston design. This in turn leads to the question of the mechanical performance of the engine and so opens up opportunities for endless discussions. The fact remains, however, that up to date no piston material has been produced that has proven entirely satisfactory. The present dowmetal piston alloy overcomes some of the undesirable qualities of other metals to such an extent that it looms up as the piston material of the future.

The general trend in the engineering world is toward light weight construction; and the discovery of aluminum alloys was hailed as a big advance in this direction. With the introduction of dowmetal, a still lighter metal becomes available. It will be remembered that aluminum casting alloys average 60 to 65 per cent heavier than dowmetal, while cast iron is 400 per cent heavier. The great gain resulting from using this featherweight metal in the reciprocating parts of an engine is apparent at once. Both block and service tests indicate a great decrease in motor vibration which gives a smoother running car, added length of life to bearings, and greater



Photomicrographs of magnesium-aluminum alloys showing the decrease in grain size as the aluminum content is increased. All specimens etched with 2 per cent nitric acid and X 200. Fig. 3—Commercial magnesium. Fig. 4—Aluminum 2 per cent. Fig. 5—Aluminum 4 per cent. Fig. 6—Aluminum 6 per cent. Fig. 7—Aluminum 8 per cent. Fig. 8—Aluminum 15 per cent

speed. A recent test by the Bureau of Standards on a certain engine showed that with standard cast iron pistons and steel connecting rods, the engine produced a maximum speed of 2400 revolutions per minute, but that on replacing this standard equipment with dowmetal pistons and connecting rods, a speed of 4400 revolutions per minute was obtained easily. This great gain in speed is a fact that recently has been taken advantage of by automobile racers. Practically all the Michigan races held this summer have been won by dowmetal equipped cars. In one instance, the preliminary races eliminated all but four cars and every one of these four had pistons of this new metal. The crowning achievement, however, occurred when dowmetal pistons carried Tommy Milton to victory in the great international race held in Indianapolis last Memorial Day.

Nonabrasiveness is another property that is fundamental and inherent in this metal. It is the only piston material that does not wear or score the cylinder. The pistons may seize because they are installed with too small clearance, or because of faulty lubrication or other motor ailments, but the cylinder block is never damaged and only in extreme cases do the pistons suffer. This can be largely attributed to the absence of hard spots and sharp needle-like crystals in the metal and also to the comparative softness of the alloy.

The absence of permanent growth and its accompanying evils—warping and distortion—are likewise characteristic of dowmetal. Their effect on poor piston fit and the binding of rings in the grooves is all too well known and needs no elaboration.

Time alone can tell what the future uses of dowmetal will be. The general characteristics of this metal indicate an extremely wide range of adaptability. Its physical properties select it as the proper choice for those construction parts where strength coupled with extreme lightness is of prime importance. The use of dowmetal as a connecting rod has been mentioned, but work along this line is in the most elementary stages. Other fields open for investigation are differential and motor housings, rear axle castings, and similar parts where there is a possibility of reducing the unsprung load of a car by the substitution of a still lighter alloy for those used at present. The aeronautical world likewise offers vast opportunities, whether it be in the structural members only or also in the wing coverings of the all-metal plane. These, however, are as yet unattacked and unsolved problems. Special alloys will have to be developed that satisfy the individual requirements in each case,—a problem well within the range of possibility.

Discussion of Mr. Gann's Paper

MR. GORDON: You spoke about heating those for an hour or two hours' time at 800 degrees Fahr. That is just below the effusion point of your metal. The metal is effused at 815 degrees Fahr.

DR. GANN: 824 degrees Fahr. is the melting point of the eutectic.

MR. GORDON: After they have been heated to that temperature, are they quenched in the furnace or in the open?

DR. GANN: We simply air cool. Due to the fact that this line *KV* in Fig. 2 comes down practically straight there is nothing to be gained by quenching. We have tried quenching, air cooling, and furnace cooling, and get practically the same results in all cases.

MR. PORTER: In connection with the assembling of the pistons, what is the capacity of the metal to retain parts assembled as compared

with cast iron? In other words, you drive a pin into cast iron and there is a rigidity in cast iron that holds that pin. This metal is soft and it seems the hole would enlarge from the shock.

DR. GANN: No sir. We have run cars with unbushed pistons for 15,000 to 20,000 miles with very satisfactory results. We have tried bushed pistons, but at the present time we are in favor of the unbushed pistons.

PROFESSOR HARDER: What technical reasons do you give for the heat treatment of this alloy?

DR. GANN: We thought it was necessary at one time in order to gain greater strength, but as it now stands, dowmetal "A" and also other alloys that have been used are all stronger than ordinary aluminum casting metals thus we are not heat treating. Furthermore, that eutectic is highly desirable. It gives a rigidity which is not obtained in the solid solution type of structure.

CHAIRMAN BOYLSTON: What is the significance of the small polyhedrons in the solid solution structure?

DR. GANN: That is a point we don't really understand. From a composite photograph of Figs. 11 to 14 we are not sure what it does mean but we think it gives an indication of the amount of solid solution present in the original casting. Referring to the original casting, Fig. 11, it will be seen that in the center of the large white area, there is practically none of the secondary structure. Referring to Fig. 12, it will be found that the secondary structure extends practically across the alloy, which we think indicates how far the solid solution extends away from the eutectic. However, that is a problem we have not solved.

CHAIRMAN BOYLSTON: What etching solution do you use for developing?

DR. GANN: A 2 per cent solution of nitric acid and water for about 5 to 10 seconds, depending on the temperature and the nature of the alloy.

MR. CLARY: In the running of pistons without bushings have you noticed that there is any apparent hardness that is greater after the piston has been run, as between the pin and piston, than in the original metal, due to grazed or otherwise affected surface?

DR. GANN: I imagine there would be. By forging magnesium or its alloys you can increase the hardness. While dowmetal "A" is not a forging alloy, we have forged a few pieces and the hardness has been increased from about 50 to 55, up to 75 and 80, but what the effect is in the bushing we have never determined. Undoubtedly the hardness is higher than in the unused piston.

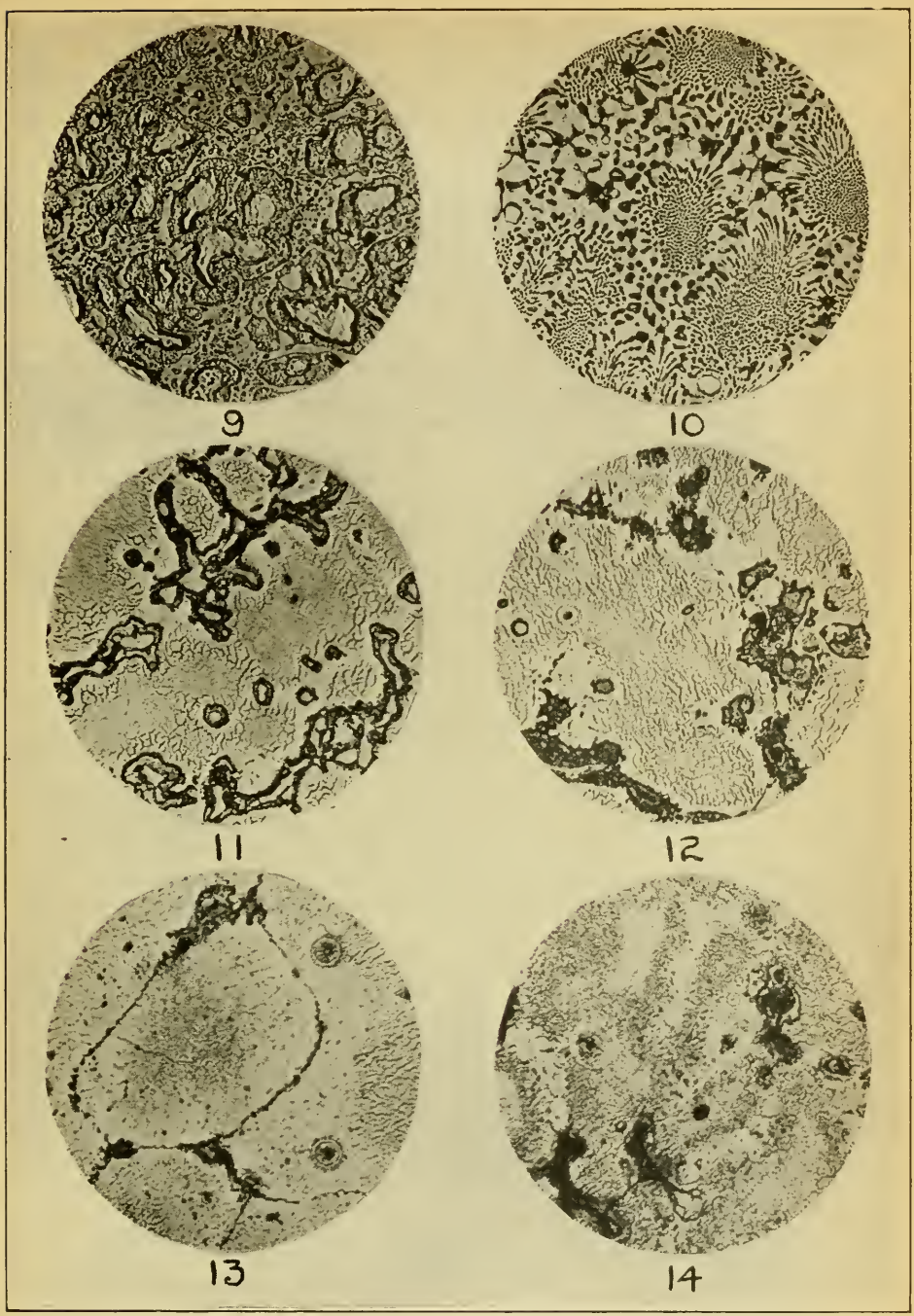
MR. CLARY: Apparently there is a grazed surface that takes place after a short time.

DR. GANN: We have never determined the hardness, so I could not definitely say, but I imagine it would be harder.

MR. SCOTT: What is the shrinkage that you allow for in the sand castings?

DR. GANN: One-eighth of an inch per foot.

MR. MCCLOUD: I noticed that the expansion, the linear expansion given for the dowmetal and also for magnesium was considerably higher than aluminum or cast iron, and also that the conductivity was lower than



Figs. 9 and 10—Photomicrographs of magnesium-aluminum alloys showing the decrease in grain size as the aluminum content is increased. Etched with 2 per cent nitric acid and X 200. Fig. 9—Aluminum 20 per cent. Fig. 10—Aluminum 31 per cent. Figs. 11-14—Magnesium-aluminum alloys of 8 per cent aluminum content showing effect of heat treatment. Etched with 2 per cent nitric acid and X 200. Fig. 11—Original casting of 8 per cent aluminum. Fig. 12—Aluminum of 8 per cent heat treated 1 hour at 820 degrees Fahr. Fig. 13—Aluminum of 8 per cent heat treated 2 hours at 820 degrees Fahr. Fig. 14—Aluminum of 8 per cent heat treated 4 hours at 800 degrees Fahr.

for aluminum. For instance, how does that affect the amount of piston clearance you have to give in your pistons?

DR. GANN: When any new piston material is brought forward you have to change the design, and all our pistons in the different types of cars had to be redesigned in order to meet these properties. The piston head is made considerably thicker than in the case of cast iron, and somewhat thicker than in the case of aluminum. This gives greater conductivity and the question of co-efficient of expansion is largely overcome.

MR. MCCLOUD: I looked that point up out of curiosity and some figures that I found stated that the heat conductivity of pure magnesium was considerably greater than that of pure aluminum.

DR. GANN: You will find all kinds of data. We think these figures are nearly correct. As previously stated, all values given here are the averages of the most reliable published data or values obtained in our own laboratory. Most of the thermal conductivity data is from our laboratory and was determined by the absolute "guard ring" method. The value for other metals as determined by this same method, checked previously published data so we believe the values here given are nearly correct.

MR. MCCLOUD: I would like to ask regarding the technique in the handling of the metal. I believe there was a German patent concerning the use of a small amount of calcium to keep down the oxidation of magnesium alloys. I wondered if any use of that idea is being made in this country.

DR. GANN: The Germans not only claim that the addition of a small amount of calcium will keep down the oxidation, but they also claim that it will increase the hardness. At the present time we have done little work along that line.

MR. MCCLOUD: It is just a case of blanketing with sufficient charcoal.

DR. GANN: We are not making definite statements as to our foundry practice at the present time.

MR. SCOTT: How does the cost of this alloy compare with other aluminum alloys?

DR. GANN: It is more expensive. Aluminum is about 25 to 30 cents a pound in the open market, and magnesium is around $1.25. There is quite a decided difference in price, and dowmetal alloys are approximately the same price. We are charging $2 a pound for castings. A set of machined Ford pistons, plain, sells for $24. They are more expensive than aluminum or cast iron, but the advantage gained more than offset the price, for example, we have never yet had a case where a piston was scored. A short time ago, Mr. Dow, the manager of the plant, was driving to Saginaw in a great hurry in his Cadillac roadster at 50 miles an hour. Suddenly there was a loud racket. He stopped and then found that he could spin the motor two or three turns whereupon that sound would start again. He coasted eight miles into Saginaw, on an average of 5 miles an hour. The car was torn down and found to be absolutely dry of oil. Several bearings were burned out but not a cylinder was scored and even with that drastic treatment only two of the pistons were scored on the side, but not enough to hurt their performance. The same pistons were put back into the car with highly satisfactory results. We have had several other instances of a similar nature, but the cylinder has never been scored.

When you consider the cost of re-boring and fixing up the cylinder it more than offsets the original cost of the pistons.

MEMBER: Do you have any trouble with metal burning?

DR. GANN: Not if proper caution is taken.

MR. GORDON: You spoke about forging. At what temperature?

DR. GANN: The only satisfactory forgings that we have had have been made from alloys of different compositions than those discussed in this paper. We used a temperature of approximately 600 to 650 degrees Fahr. Other conditions were similar to those used in standard steel forging practice.

FRACTURE TEST ON STEEL TO DETERMINE ITS QUALITY

By W. J. Priestley

THE bulk of steel entering into finished machine parts in this country is forged, heat treated, and machined in other plants than the plant in which it is melted and cast. Large quantities of high grade alloy steel, high carbon steel, and tool steel are handled in this manner. The consumer purchases the steel on its chemical analysis and surface inspection, no reference being made to the record of manufacture other than that the steel shall be made by the acid open-hearth, basic open-hearth, electric or crucible process. In some cases, the method of melting is not specified.

Frequently it happens that steel purchased in this manner is rejected after heat treatment or after machining due to defects which were not apparent in the purchased bloom, billet, or bar stock. Due to the fact that a customer may purchase only a small portion of the original heat of steel, it would be impracticable for him to demand with his purchased order of steel, the melting record of this steel; furthermore, if this record were furnished, the consumer might not be able to interpret the same intelligently and know whether or not he was getting a satisfactory heat of steel.

In cases where complete detail record of manufacture of steel forgings have been available, it has been found that a simple fracture test taken from the end of a forging, billet, or rolled bar stock, furnishes more conclusive data than many other tests which are more elaborate and more expensive. This test has been used for some time past for determining pipe in rolled stock. In this instance, the plane of the fracture is at right angles to the direction of rolling. Purchasers of high grade alloy steel and tool steel will find a fracture test equally serviceable and practicable for a determination of slag, inclusions, flake, blow holes, pipe, and excessive segregation, if taken so that the plane of the fracture is parallel to the direction of forging or rolling.

The test consists of sawing a disk about 1¼ inches thick from one end of the forging or bloom. If this small disk is quenched slightly above its critical temperature, drawn between 900 and 1100 degrees Fahr., and then broken in two, it will give a fracture parallel to the direction of forging or rolling which will disclose the texture of the metal. Flake, slag, blow holes, pipe and excessive segregation may be detected easily by means of this fracture test.

This test should supplement the usual test for chemical analysis and surface inspection. It affords a means of rejecting, before forging, heat treating and machining, any steel which contains any of the foregoing defects. In many cases steel with inherent defects is taken up for manufacture and when finally rejected, is blamed upon improper heat treatment on account of not having knowledge of these inherent defects.

Figs. 1 and 2 show disks taken from forgings as large as 10, 13, and 18 inches in diameter. It will be seen from Fig. 1 that the disks were broken with great difficulty after a single quench and draw. The way in which these disks bent without breaking gave almost positive proof

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A paper presented at the Indianapolis Convention. The author is superintendent of the hot metal division, United States Naval Ordnance Plant, Charleston, W. Va.

that subsequent tensile tests from these forgings would be satisfactory. Four bars taken at right angles to the direction of forging of these blooms showed the following physical results:

Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
95,400	61,000	25.2	53.2
97,500	68,300	26.	58.1
100,000	62,500	23.6	50.8
100,100	68,400	23.6	50.5

Attention is invited to the fact that these bars were taken at right angles to the original axis of the ingot and across the grain with respect to the way the metal was forged. This steel was 0.38 per cent carbon, and about 2.75 per cent nickel.

Fig. 1—Disks taken from 0.38 per cent carbon, 2.75 per cent nickel steel forgings and broken with great difficulty after a single quench and draw. The way in which they bent without breaking gave almost positive proof that tensile tests would be satisfactory

Fig. 2 shows three similar disks taken from other blooms. The top disk discloses minute inclosures of slag in the fracture. These may be seen by closely examining the photograph. They are about as wide as a needle and vary from ¼ to ½-inch in length. Physical test bars taken from this forging at right angles to the axis showed the following physical tests:

Tensile strength, pounds per square inch	94,000
Elastic limit, pounds per square inch	70,000
Elongation, per cent	12.2
Reduction in area, per cent	30

The middle disk, Fig. 2, shows a fracture of steel which is almost entirely free from slag or other impurities. Tensile bars taken from this disk showed the following:

Tensile strength, pounds per square inch	97,000
Elastic limit, pounds per square inch	70,000
Elongation, per cent	26.4
Reduction in area, per cent	62

The bottom disk, Fig. 2, contains bright silky spots, generally termed "snow flakes". These are very easily distinguished in the photograph. A tensile bar taken at right angle to the axis of this forging showed the following:

Tensile strength, pounds per square inch	94,900
Elastic limit, pounds per square inch	67,500
Elongation in area, per cent	11.4
Reduction in area, per cent	24.9

This information is furnished with the idea that it may be of some benefit to heat treaters who do not melt their own stock but purchase it in the form of blooms, or billets. This is an inexpensive test and could be taken at the rolling mills or forge plants before shipment to the ultimate consumer. The saving effected by rejecting unsatisfactory steel before machining and heat treating would more than offset the slight cost of taking fracture tests of forgings, blooms or bar stock.

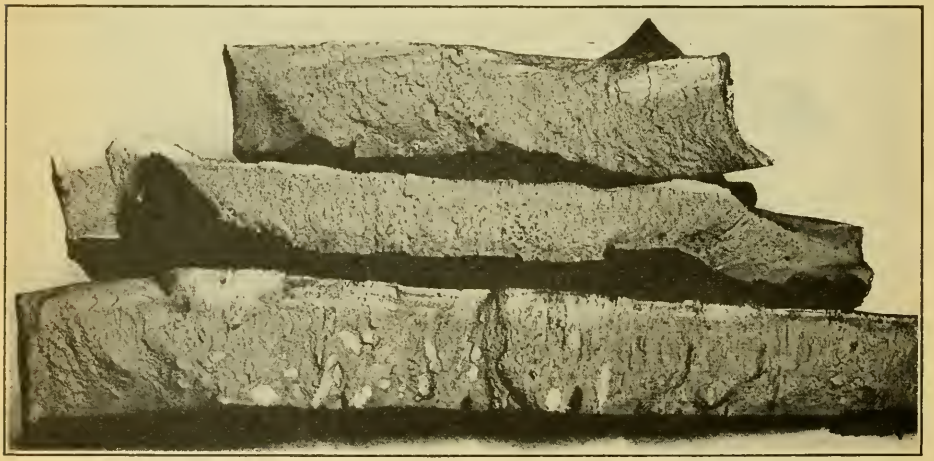


Fig. 2—Three similar disks taken from blooms. The top disk discloses minute inclosures of slag in the fracture. The middle disk shows a fracture almost entirely free from slag or other impurities. The bottom disk shows bright silky spots known as "snow flakes"

ROMANCES OF METAL WORKING—TWO FAMOUS ARMORERS

By H. H. Manchester

IN THE 15th century the two great schools of armor making were the Italian and the German, which had by this time surpassed in quantity, if not in quality, the famous Toledo blades of Spain.

In Italy the armorers were located in all of the principal cities, with those of Milan, Florence, and Venice perhaps the most famous. A representative armorer of Venice was Vittore Camelio, who also developed a rather important step in metal working.

He lived in the latter half of the 15th century, and was noted for his light steel armor of a very high temper, as well as for the elasticity and indestructibility of his swords.

Camelio was not only an armorer, but a medal maker and an engraver. One day, so the legend runs, he used one of his swords to slice off a bar of gold which had been sent him for medals. This was done so easily that he realized more than ever the fact that he could produce steel which would cut the other metals. From this idea, he developed a steel die, which he used at first to cut out the blanks for medals, and later, it is said, to stamp the face of a coin. At any rate, the senate of Venice in 1509 gave him a patent for this device for five years, which is comparatively good proof that there is much truth in the story.

A fair representative of the German school of armor making was Conrad Seusenhofer, who lived in the last of the 15th and the first of the 16th century.

In 1504 we find him enlarging his workshops at Insbruck with money advanced from the government, but later we find that this was to be deducted from his pay.

He developed the fluted style of armor, which was for some years the height of fashion, and evolved a number of special tools to produce this. Another tool of importance which he is credited with improving, is the heavy shears which could cut thin plates of iron.

He developed several new methods of armor plate construction, but these were not at all in favor with Maximillian, the emperor, who said to him: "Make my armor only in accordance with my instructions, for it is I, not you, who must wear it."

In 1511 Seusenhofer complained that the mine master, Kugler, was sending him poorer metal, and suggested that the armor plate from it be called Milanese, which indicates that he thought the Innsbruck steel better than the Italian. It also shows that at that time the quality of the steel produced could not be altered at will by the smith, but depended largely on the nature of the iron with which he had to work.

The armorers of the time were always having trouble collecting the pay for their work, and frequently the only method of assuring it, was not to deliver the armor until paid for. Seusenhofer was apparently using this method to collect from Maximillian, or his government, during one of the wars of the period. This finally led to there being a shortage of armor, whereupon Maximillian in wrath sent word that if the armor were not forthcoming that the armor makers would be put in the front rank without armor, so that they could appreciate for themselves how it felt to fight without proper protection.

Reprinted from page 404 of the March 16 issue of the *American Machinist*.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

CORRECTS CARBON CONTENTS

IN THE paper "Do Alloy Carbonizing Boxes Pay?" by C. M. Campbell, which appeared on page 495 of the March issue of TRANSACTIONS, the author desires to correct two errors which appeared in the original manuscript. In the first line of the last paragraph on page 495, the word "over" should read "under," thus the line should read "An iron-chromium silicon alloy which analyzes: Carbon under 0.50." In the last line of the third paragraph on page 496, the word "less" should read "greater," therefore the corrected sentence will read "This iron-chrome-silicon alloy can be cast in either green or dry silica sand molds when the carbon content is greater than 0.25 per cent."

BRINELL HARDNESS FIGURE APPEARS IN ERROR

THROUGH typographical error one of the actual Brinell hardness figures was given incorrectly in the paper "New Development on the Influence of Mass in Heat Treatment" by E. J. Janitzky, which appeared on page 377 of the February issue of TRANSACTIONS. On page 381 in the second column headed "Actual Brinell hardness," the figure in the fifth line should appear as 248 instead of 348.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. *What is needle bar stock?*

QUESTION NO. 6. *Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?*

QUESTION NO. 7. *May tools be heat treated properly in a furnace in which copper is present?*

QUESTION NO. 8. *What is the effect of high and low silicon in tool steel?*

QUESTION NO. 9. *In carbonizing does not the carbon increase slightly even in the core section?*

QUESTION NO. 10. *What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?*

QUESTION NO. 11. *Has high speed steel ever been carbonized and if so what were the results?*

QUESTION NO. 12. *How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?*

QUESTION NO. 13. *A swaging die for tubing receives* 3600 *blows per minute. It has been found that a scleroscope hardness of about* 95 *is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?*

QUESTION NO. 14. *What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.*

QUESTION NO. 17. *For some time past we have been water quenching steel castings in order to improve their physical properties. These castings are mostly shrouded pinions and plain rollers, weighing from* 150 *to* 500 *pounds each. These pieces would be immersed in the water bath for a short period of time, usually from one to two minutes and then withdrawn and*

allowed to cool in the air. Our results have been satisfactory but we feel that we can improve this method somewhat by a slight modification in the treatment. In order to relieve cooling strains, one suggestion is that we provide a tank filled with infusorial earth in which the castings would be placed in order that cooling might be slow and uniform. Another suggestion is that instead of using a plain water bath, we introduce sodium hydrate in order that the quenching may not be quite so severe. We would like to know which of the above plans would be the better or if there is any other better plan which could be suggested. We do not care to use oil because of its expense.

NOTE. Rollers may break in the flange a month or more after above treatment. Loss at present is 2 per cent. Pinions, after above treatment, are drawn in furnace to 1200 degrees Fahr. for toughness. If drawn shortly after quenching there is no trouble, but this is not always practicable when working day turn only. If allowed to stand in air after quenching, cracking may result, hence the suggestion for covering with infusorial earth or ashes. We have had only one batch to show cracks.

ANSWER. By A. H. Putnam, testing engineer, 1710 East Twelfth street, Davenport, Ia. It is extremely difficult to make suggestions which will lessen the loss from cracks after quenching steel castings without having more information of this particular case. Some of the factors which are directly or indirectly responsible for these cracks will be outlined briefly below.

It is imperative that the approximate chemical composition of each lot of castings be known as it will be necessary to regulate the quenching and drawing temperatures accordingly. No doubt the loss from cracks will be larger in the casting heats showing a higher carbon content than from heats with a lower carbon content. The method of annealing which is used prior to heat treatment is often responsible for cracks in quenched castings when the original casting structure is not broken down by a sufficient anneal. If ferromanganese or ferrosilicon additions are made in the ladle just prior to pouring castings and the ferroalloys have not completely diffused, this will no doubt cause trouble when the castings are quenched. The length of time the castings are allowed to soak just prior to quenching is very important. The length of time the castings are held at the drawing temperature is more important. The length of time the castings are allowed to remain in the quenching bath will depend largely upon the carbon content and the shape and weight of the casting being quenched. The physical properties which are desired will to a large extent regulate the heat treatment. If the physical properties required are not too severe, often times an air quench or cooling in an air blast from a temperature above the upper critical point and using a low draw will furnish the desired results.

QUESTION NO. 18. *What is the relationship between Brinell and Scleroscope hardness?*

ANSWER. By J. Fletcher Harper, research engineer, Allis-Chalmers Mfg. Co., Milwaukee.

At various times the members of the society have brought up the question as to the relation which exists between the Brinell and scleroscope numbers. The Allis-Chalmers Mfg. Co. has prepared the accompanying two charts with this information for the guidance of their engineers.

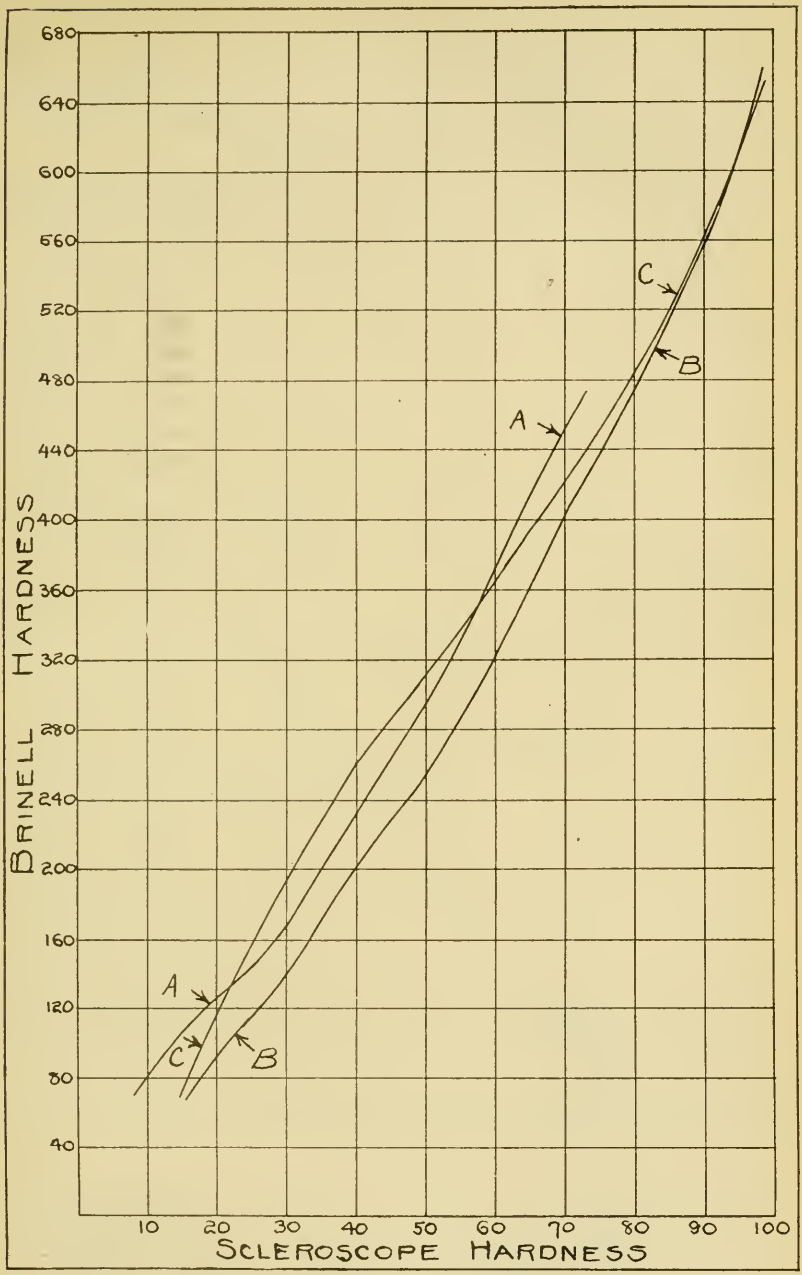


Fig. 1—Curves showing comparisons between Brinell and scleroscope hardness. Curve *A* produced by Allis-Chalmers Mfg. Co., using steel ball at 3000-kilogram pressure. Curve *B* produced by Shore using diamond ball at various pressures. Curve *C* produced by Shore using steel ball at 3000-kilogram pressure

Fig. 1 is the comparison between Brinell and scleroscope numbers. Curves *B* and *C* were prepared by A. F. Shore and were presented by him before the British Iron and Steel Institute in September, 1918. Quoting from Mr. Shore's article: "Curve *C* is the relation between the scleroscope and ball tests from the hardest to the softest metals, using 3000 kilograms throughout under 10-millimeter steel ball. It was not found possible to obtain a satisfactory conversion curve, as its wavy appearance indicates. This is probably due to the cause of excessive pressures.

"From approximately 700 Brinell to 550, wide discrepancies are caused by the flattening of the ball. From 550 down to about 200 Brinell, abnor-

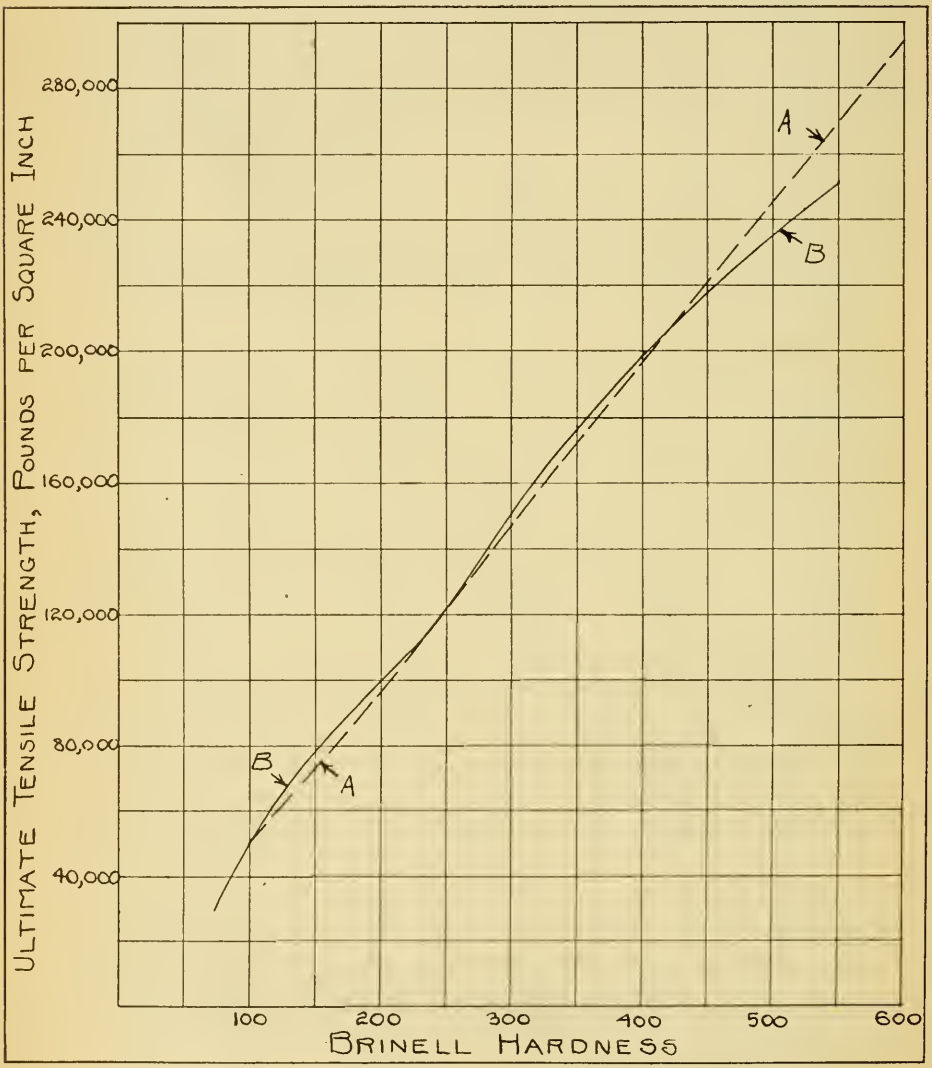


Fig. 2—Curves showing comparisons between ultimate tensile strength and Brinell hardness numbers. Curve *A* reproduced from *Making, Shaping and Treating of Steel*, by J. M. Camp and C. B. Francis. Curve *B* produced by the Allis-Chalmers Mfg. Co.

mally high readings are obtained, due to the superhardening of this series of metals, which is necessarily possessed of marked toughness. Below 250 similar superhardening occurs, but Brinell readings have a tendency to fall below the best average line, because the superhardening is neutralized by flow in the metal. In order that these tendencies may be shown more clearly, a comparison is given in curve *B*. Curve *B* is the relation of ball test and scleroscope using 62, 250, 500 and 750 kilogram pressures, respectively. Above 325 Brinell or 60 scleroscope, a diamond sphere 10 millimeters in diameter was used, because of the flattening of the steel ball."

Curve *A* is the one plotted at the Allis-Chalmers Mfg. Co., from approximately 500 readings covering various classes of materials. While this curve is subject to the same discrepancies of superhardening, etc., referred to by Mr. Shore; together with possible slight errors due to grain size, nature of surface, etc., it has been found an excellent approximation for commercial practice. All readings were made by the same two operators checking each other; and in all cases a buffed surface was used.

Fig. 2 shows the comparison between Brinell hardness and tensile strength. Curve *A* is taken from the table in the *Making, Shaping and Treating of Steel* by J. M. Camp and C. B. Francis. They publish the following: "It is both a curious and a significant fact that the Brinell hardness number bears a close relation to the ultimate strength. * * * * * * * This relation it will be observed, is approximately 500, and holds for all grades of carbon steel whether they be heat treated or in the natural state as forged or rolled. For this reason the Brinell test is applicable to the rapid testing of steel from which sample for the tensile test cannot be obtained."

Curve *B* is the relation established between the Brinell hardness number and the tensile strength of a large number of samples by the Allis-Chalmers Mfg. Co.

Following are given some of the recent references to hardness testing:

"Comparison of Five Methods used to Measure Hardness," by Ralph P. Devries, Technologic paper No. 11, Bureau of Standards.

"Hardness Testing," by A. F. Shore, paper read before the Iron and Steel Institute Sept. 12, 1918. *Engineering,* Oct. 18, 1918, *Journal* American Steel Treaters Society January, 1919.

"The Hardness Testing of Metal," *Journal* of Mechanical Engineering, July, 1921.

"The Use of the Scleroscope on Light Specimens of Metals" by Fred S. Tritton, *Engineering,* Sept. 30, 1921.

"Hardness Variations in Heat Treated Steel," by Carle R. Hayward, *Chemical and Metallurgical Engineering,* Oct. 12, 1921.

"Scleroscope Hardness of Steel Balls," by Arthur L. Collins, *Iron Age,* Dec. 1, 1921.

"Physical Properties of Material," Bureau of Standards Circular No. 101, Feb. 9, 1921.

"The Relation Between Maximum Strength, Brinell Hardness and Scleroscope Hardness in Treated and Untreated Alloy and Plain Steels," by Robert A. Abbott, *Proceedings* of American Society for Testing Materials, 1915, Volume XV.

QUESTION NO. 20. What are the causes of warping in the heating and cooling of steel?

QUESTION NO. 22. Can ghost lines be eliminated by heat treatment?

NOTE. A difference of opinion exists on this subject as shown by the four brief answers submitted with the question. N. B. Hoffman says: Ghost lines can not be broken. The carbon can be recrystallized but the

nonmetallics remain. W. J. Merten says: Ghost lines can be eliminated by heating to a very high temperature and cooling to the critical point rapidly. Then heat treat from this point. A. M. Cox says: Ghost lines can be prevented from forming. W. B. Crowe says: Ghost lines can not be eliminated but may be modified.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?

QUESTION NO. 24. What methods can be suggested for brazing high speed sheet steel strips together, preferably during the hardening operation? A spelter of copper, tin, aluminum and borax finely pulverized seems to interfere with the proper hardening. The portion of the tool brazed must maintain a keen edge and have good red hardness.

ANSWER. By W. L. Appel, assistant director testing department, E. C. Atkins & Co., Indianapolis. A cement is now on the market for cementing high speed steel or stellite to a low carbon base in making tools for all purposes, whether it be to lower the cost of a solid high speed steel tool or to alleviate the brittleness of a tool. The writer has had success with this cement in repairing broken high speed tools and has used it for cementing high speed steel bar stock together. Cementing is carried out in the same operation as the hardening of the high speed steel. The cement, which is in the form of a fine powder, is placed between the scale or rust-free surfaces of the steel to be cemented together. The pieces then held in the proper position are placed in the hardening furnace and heated to the desired hardening temperature. The cement melts at 2200 degrees Fahr. and acts as an alloying agent between the surfaces of the steel. After the proper hardening temperature is reached, the excess cement is squeezed out by a slight pressure and the whole quenched in the desired bath. Later this tool or high speed part may be drawn at any temperature or even annealed and rehardened.

QUESTION NO. 25. In hammering down some high speed steel scrap, first a heavy hammer then a light hammer was used to reduce the size. The pieces were packed in charcoal and annealed at 1550 degrees Fahr., with the result that a very hard case was produced. Some pieces were annealed without putting them under the light hammer and the case did not result. Open annealing was then tried on both kinds but no case was obtained. What caused the case mentioned above?

ANSWER. Charcoal under proper conditions gives internal combustion thus raising the temperature in the boxes to within the carburizing zone.

QUESTION NO. 26. Frequently checks and cracks appear in case hardened and high carbon steel parts after lapses of various times. These parts apparently come from the grinders in perfect condition. The cracks are sometimes radial and sometimes not. Regrinding and changing wheels, speeds, grades, feeds and refrigerant do no good. Why do these cracks occur?

ANSWER. I can not see where the hardening room can be blamed al-

though the steel may be dirty or faulty. However, faulty steel should show up in the hardening room. It would be well to look into the grinding and to get the advice of a grinding expert on the job. To ascertain if checks will grow, start the piece "breathing," that is, cool in kerosene to about 20 degrees below zero and heat to almost a drawing temperature. Repeat the operation several times.

QUESTION NO. 27. In grinding high speed work a soft film often is left on the piece. Why does this happen?

ANSWER. The grinding probably develops this film.

QUESTION NO. 28. Does it seem that dry grinding will generate enough heat to draw high speed steel?

ANSWER. Absolutely. It is necessary only to get above 1200 degrees Fahr. to start the softening and this is very easy as high speed steel does not give off many sparks and therefore will not give much notice of its heat.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

ALLOYS AND ALLOY STEELS

CHROME-MOLYBDENUM STEEL APPLICATIONS FROM THE CONSUMERS VIEWPOINT. By C. N. Dawe, *Journal* of the Society of Automotive Engineers, Vol. 10, Page 47.

Tensile tests were made on 400 heat treated test pieces of chrome-molybdenum, chrome-vanadium, chrome-nickel and chrome steels, the heat treated stock varying in size from ⅞-inch rounds to 2-inch squares. The heat treatment consisted of a quench from 1475 to 1659 degrees Fahr., depending upon the type of steel, followed by a draw. Three drawing temperatures, namely, 1000, 1100 and 1200 degrees Fahr. were used on each type of steel. Comparison of results by means of Chandler's merit index, showed the chrome-molybdenum steel to have a decided advantage over the other grades tested. Carbonizing tests with chrome-molybdenum steels did not give as uniform results as could be desired. Nickel-molybdenum steels have shown themselves more satisfactory in carbonizing operations.

THERMAL EXPANSION OF NICKEL, MONEL METAL, STELLITE, STAINLESS STEEL, AND ALUMINUM. By W. H. Souder and P. Hidnert, Bureau of Standards, Scientific Paper No. 426.

Thermal expansion curves were established for 10 samples of nickel containing 94 to 99 per cent of the element, ten samples of monel metal, five samples of various grades of stellite, two samples of stainless steel and two samples of aluminum. For all but the stainless steel, the curves cover the range from room temperature to 600 degrees Cent. For the stainless steel the curves extend to 900 degrees Cent.

MANUFACTURE AND PROPERTIES OF STEEL PLATES CONTAINING ZIRCONIUM AND OTHER ELEMENTS. By G. K. Burgess and R. W. Woodward, Bureau of Standards, Technologic Paper No. 207.

The investigations were made by the Bureau of Standards and the Bureau of Mines to furnish information to the army and navy on light armor plate. One hundred and ninety-three heats of steel containing varying combinations of the following principal variable elements: carbon, silicon, nickel, aluminum, titanium, zirconium, cerium, boron, copper, cobalt, uranium, molybdenum, chromium and tungsten were studied. Three per cent nickel steel deoxidized with aluminum gave a tensile strength of 300,000 pounds per square inch and is recommended for structural work. The action of the individual elements is described in detail.

FATIGUE FAILURE

REMARKS ON FATIGUE FAILURE OF METAL PARTS, THEIR CAUSE AND PREVENTION. By H. C. Knerr, *Forging and Heat Treating,* Vol. 8, Page 40.

The conditions which influence fatigue failure in metals are (a) the number of repetitions or cycles of stress applied in the lifetime of the piece; (b) the range of stress for each cycle; and (c) the presence of points at which stresses may become localized, such as notches, sudden changes of cross section, or irregularities in the metal, such as slag particles. A specific case of failure is sighted in which appreciable amounts of slag were found in the metal.

FERROUS MATERIALS

CONTINUOUS DIE ROLLING. By G. R. Norton, *Journal* of the Society of Automotive Engineers, Vol. 10, Page 43.

The production possibilities and manufacturing methods used in die rolling are described. The active surface of the rolls is built up from forged or cast rings instead of sinking impressions into the ordinary roll. Metallographic examination shows that this process gives a very uniform, small-grained product. Cost and equipment are discussed in very general terms.

PERTINENT FACTS CONCERNING MALLEABLE IRON CASTINGS. By Enrique Touceda, *Journal* of the Society of Automotive Engineers, Vol. 10, Page 53.

The article is primarily intended for the purchasing agent and the structural engineer. The difficulties encountered in the foundry, such as gating and pattern design, are discussed. The sources of trouble in machining malleable castings are outlined. Figures are given on the tensile properties of malleable iron and the characteristics of its chief ferrous competitors are covered briefly.

FORGING PROBLEMS

HISTORICAL SKETCH OF DEVELOPMENT OF FORGING. By S. L. Goodale and R. H. McMillan, *Forging and Heat Treating,* Vol. 8, Page 23.

A very general discussion of the development of the forging hammer is given.

DIE BLOCKS AS SEEN BY THE DROP FORGE PLANT. By A. A. Blue, *Forging and Heat Treating,* Vol. 8, Page 34.

The qualities desired in die blocks are reviewed and present die block practice is discussed. It is suggested that the die block situation would be greatly improved through the use of specifications on composition and physical properties, standardization of sizes, limits of tolerance. etc.

MAKING THE LATROBE HIGH SPEED TWIST DRILL. By S. A. Hand, *American Machinist,* Vol. 56, Page 246.

In making a 1⅜-inch drill an 8-inch ingot is cogged down to a 2-inch square from which the drill blanks are rolled out in seven passes. The blanks are carefully annealed previous to the twisting and machining operations. After machining and before attaching the sockets, the drills are quenched in oil from 2500 degrees Fahr. and drawn at 1100 degrees Fahr.

METALLOGRAPHY AND HARDNESS THEORY

THE SLIP INTERFERENCE THEORY OF THE HARDENING OF METALS. By Zay Jeffries and R. S. Archer, *Chemical and Metallurgical Engineering,* Vol. 26, Page 249.

A general reply is made to the various comments published since the original presentation of the theory. Present allotropic theories of hardening must be discarded since martensite is shown to be made up of alpha iron.

THE COLLOIDAL STATE IN METALS AND ALLOYS—IRON AND STEEL. By J. Alexander, *Chemical and Metallurgical Engineering,* Vol. 26, Page 201.

Beta iron is accounted for by assuming it to be alpha iron containing colloidally dispersed gamma iron. The metallographic constituents are discussed from the standpoint of colloidal solutions. Some consideration is also given to the hardness of colloids.

GRAIN GROWTH AND RECRYSTALLIZATION IN METALS. 1. DEFINITIONS. By Zay Jeffries and R. S. Archer, *Chemical and Metallurgical Engineering,* Vol. 26, Page 343.

Recrystallization is defined and a list of recrystallization temperatures are given. Methods of measuring grain size are presented and discussed.

REVIEW OF IRON AND STEEL LITERATURE FOR 1921. By E. H. McClelland, *Forging and Heat Treating,* Vol. 8, Page 4.

A list is given of articles and books on metallurgy, foundry practice, heat treatment, etc., published during the year.

THEORY OF THE HEAT TREATMENT OF STEEL. By W. M. Mitchell, *Forging and Heat Treating,* Vol. 8, Page 52.

The nature of steel is briefly discussed and the significance of the critical points is considered. The constitution of steels of various carbon contents is described and illustrated with photomicrographs.

THE X-RAY IN METAL ANALYSIS. From a paper by Dr. R. Schenck, *Iron Age,* Vol. 109, Page 531.

Heycock and Neville first used X-rays in the examination of alloys some 20 years ago. Their investigations were made on gold sodium alloys, whose constituents possessed great difference in opacity to X-rays. Plain carbon, and nickel, manganese and chromium alloy steels cannot be investigated in the above manner in that the constituents are of nearly equal opacity. Tungsten steels can be analyzed by this method, it being possible to obtain the tungsten content of the steel very accurately from the photographs. The more recent investigations in the X-ray examination of metals have been on the nature of the atomic constitution and were inspired by the ideas of von Laue.

THE STUDY OF COALESCENCE IN STEELS AND ITS COMMERCIAL RESULTS. By A. Portevin and V. Bernard, *Engineering,* Vol. 63, Pages 28-31 and 59-61.

For a given steel the factors which govern the amount of coalescence of the cementite above the A_1 range are: (a) Rate of cooling; (b) temperature and duration of initial heating; and (c) temperature alternations above A_1. The factors governing coalescence below the A_1 range are: (a) Temperature and duration of maintenance at this temperature; (b) previous mechanical treatment; (c) previous heat treatment. The carbon content and the presence of many alloying elements influence the coalescence in any group of steels. Changing the cementite of a steel from the lamellar to the globular form reduces the hardness about 50 per cent. Globular cementite reacts much more slowly to heat treatment than does the lamellar form.

NITROGEN IN STEEL

THE DETERMINATION OF NITROGEN IN STEEL. By F. Hurum and H. Fay, *Chemical and Metallurgical Engineering,* Vol. 26, Page 218.

The literature on the subject was consulted and of the methods found the iodide-iodate method, first reported by Grabe and Petren, was selected as the most practical. Five grams of steel are dissolved in HC_1 in a special container, a $NaOH$-$KMnO_4$ solution is added and the ammonia formed is distilled into H_2SO_4. The excess H_2SO_4 is determined by the iodide-iodate method. Specific directions are given for preparing the reagents and making the determinations.

WELDING

IMPORTANCE OF MANAGERIAL UNDERSTANDING OF WELDING. By G. O. Carter, *Iron Age,* Vol. 109, Page 323.

Welding has many applications in the steel industry, but the developments of its use have largely been left to the individual workman or to a foreman. Managers are just beginning to appreciate its possibilities. Methods of checking the ability of welders are given, together with some of the prominent uses.

WELDING RODS FOR OXYACETYLENE WELDING. By J. R. Dawson, *Iron Age,* Vol. 109, Page 468.

The welding of carbon and high speed steel, cast iron and nonferrous products, is considered and the selection of the proper welding rod for each case is discussed. It has been found that some batches of steel will not weld properly, even though chemical and metallographic examination revealed nothing out of the way. The article is illustrated with numerous photomicrographs.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ADAMS, J. N., (M-10), Standard Oil Co., Richmond, Cal.
ANDERSON, H., (M-3), Mahr Mfg. Co., Minneapolis, Minn.
ANDREWS, J. L., (M-3), 6078 Northfield Ave., Detroit, Michigan.
BOLDUC, E. W., (M-2), 50 Mills St., Bristol, Conn.
BROOKS, W. C., (A-4), P. O. Box 447, Worcester, Mass.
COLONIAL STEEL CO., (S-3), Keystone Bldg., Pittsburgh, Pa.
COOK, F. H., (A-2), Crucible Steel Co. of America, Philadelphia, Pa.
COOLIDGE, R. H., (M-3), U. S. Ball Bearing Co., Chicago, Ill.
FERRY, O. N., (M-3), 111 Coniston Ave., Waterbury, Conn.
FIRTH STERLING STEEL CO., (S-2), McKeesport, Pa.
GOBUS, A., (M-3), Doehler Die Castings Co., Brooklyn, N. Y.
GUNN, F. R., (M-3), 2313 W. Atlantic St., Philadelphia, Pa.
HAINES, G. D., (M-3), 4150 N. Cicero Ave., Chicago, Ill.
HOCKING, H., (M-3), 3106 Eastlawn Ave., Detroit, Mich.
HOLMLAND, H., (M-3), 60 Mill St., Worcester, Mass.
HORTVET, R. M., (M-3), Mahr Mfg. Co., Minneapolis, Minn.
HUGHES, E. T., (M-2), 369 Beaver St., Beaver, Pa.
JACOBSON, H. W., (M-3), Gould & Eberhardt, Newark, N. J.
JOHNSON, W. R., (Jr.-3), 200 Knapp St. Apt. 3, Milwaukee, Wis.
JONES, H. I. (M-3), 654 Pearl Pl., Elmira, N. Y.
KELLEY, J. E., (A-3), Simonds Mfg. Co., Fitchburg, Mass.
KRAUSE, A. E., (M-3), 23 Wall St., Bethlehem, Pa.
KUMMER, R., (A-2), 469 Elliott Ave., Cincinnati, Ohio.
LARSON, C. L., (M-12), 23 Lakewood St., Worcester, Mass.
LARSON, P. A., (M-3), 17 Ekman St., Worcester, Mass.
LYONS, T. G., (M-2), 855 Cornwall St., Philadelphia, Pa.
MAIER, E. J., (M-2), 6545 Van Dyke St., Tacony, Philadelphia, Pa.
McCALLEN, T. P., (M-3), 311 Mayran Ave., Pittsburgh, Pa.
MILLER, C. C., (M-3), 2427 4th St., Minneapolis, Minn.
MILLER, J. R., (S-3), Jones & Laughlin Steel Co., Pittsburgh, Pa.
MINUSE, A. W., (A-4), Room 1027, 165 Broadway, New York City.
MORAN, J. J., (Jr-3), 166 E. 88th St., New York City.
MORRILLON, E. E., (M-12), 202 Miley Ave., Indianapolis, Ind.
MURDO, E. E., (M-2), Park Mfg. Co., St. Paul, Minn.
NOVAK, A., (M-3), 9114 Kennedye Ave., Cleveland, Ohio.
NUTTAL, R. D. CO., (S-3), Pittsburgh, Pa.
PATERSON, J. A., (M-3), 4 S. Buffum St., Worcester, Mass.
PFLUEGER, J. E., (M-3), Enterprise Mfg. Co., Akron, Ohio.
PITTSBURGH VALVE FDRY & CONSTRUCTION CO., (S-3), Pittsburgh, Pa.
PRATT, JONATHAN, (Jr-3), 99 Miserole Ave., Brooklyn, N. Y.
REA, J. C., (S-3), Oliver Iron & Steel Co., Pittsburgh, Pa.
RIDDILE, F. C., (M-2), 419 College Ave., Oakmont, Pa.
ROTHERHAM, G. C., (M-2), 6609 Hegerman St., Tacony, Phil., Pa.
SCHWENTLER, F. E., (M-3), 1932 N. Broadway, St. Louis, Mo.
SCIENTIFIC MATERIALS CO., (S-3), 717 Forbes St., Pittsburgh, Pa.
SCOTT, HOWARD, (M-3), 3825 14th St., Washington, D. C.
SHEFFIELD PUBLIC LIBRARY, (S-12), Surrey St., Sheffield, England.
SMUCK, JAMES, (M-10), Croix (Nord) France.
SNYDER, Q. S., (S-3), 41st & Willow Sts., Pittsburgh, Pa.
SQUIRES, A. J., (A-3), Somerville, N. J.
TENNESSEE COAL, IRON & RAILROAD CO., (S-10), Birmingham, Ala.
TRAEGER, A., (S-3), E. Leitz, Ltd., 60 E. 10th St., New York City.
TICHY, V. L., (M-3), 3178 W. 56th St., Cleveland, Ohio.

TRAPP, A. J., (M-3), 106 Oak St., Southington, Conn.
TRUMBORE, H. C., (M-3), Doehler Die Castings Co., Toledo, Ohio.
UHL, RAYMOND, (M-3), 6337 Torresdale Ave., Tacony, Philadelphia, Pa.
UNDERWOOD, W. A., (M-1), 775 Southbridge St., Worcester, Mass.
UNION STEEL CASTING CO., (S-3), Pittsburgh, Pa.
UNITED ENGINEERING & FOUNDRY CO., (S-3), Pittsburgh, Pa.
VANADIUM CORP. OF AMERICA, (S-4), Bridgeville, Pa.
VULCAN CRUCIBLE STEEL CO., (S-3), Aliquippa, Pa.
WALLEY, W. H., (M-3), 2519 Washington St., Minneapolis, Minn.
WEILAND, W. F., (M-3), 1237 Rebecca Ave., Wilkinsburg, Pa.
WILLIAMS, H. R., (A-2), Electric Alloy Steel Co., Philadelphia, Pa.
WRIGHT, F. G., (M-1), 1518 Euclid West, Detroit, Michigan.

CHANGES OF ADDRESS

BARDWELL, J. P.—from E. T. Ward Sons, New York City to 1834 77th St., Brooklyn, N. Y.
BERRYMAN, H. H.—from Pheoll Mfg. Co. to 1525 S. 57th Ct., Chicago, Ill.
BRADFORD, J. F.—from 1916 West Blvd. to 1906 E. 84th St., Cleveland, O.
BROOKS, C. A.—from 1393 Broadway, Rensslair, N. Y. to 100 Colonial St., Albany, N. Y.
BURGDUFF, H. M.—from 12 Mattie St., Auburn, N. Y. to Clayville, N. Y.
BUSH, A. T.—from 1414 Kanawah, Charleston, W. Va., to 109 S. Hill St., Massillon, O.
CASSIDY, A. G.—from 27 Banks St., Waltham, Mass. to 526 5th Ave., N. St. Petersburg, Fla.
CINIOTTI, G. E.—from 1021 Park Bldg. to 726 North Beatty St., Pittsburgh.
COPE, L. S.—from 920 Mary St., Ann Arbor, Mich. to National Screw & Tack Company, Cleveland, Ohio.
CUNNICK, P. C.—from 2807 E. Locust St. to 141 Forest Rd., Davenport, Ia.
DALTON, J.—from 206 Broad St., Charleston, W. Va., to 50 Elmhurst Ave., Elmhurst, N. Y.
DAVIS, G. F.—from 206 Broad St., Charleston, W. Va., to Bowling Green, Mo.
FULLMORE, H. W.—from 23 Curry St., S. Charleston, W. Va. to 151 E. Durham St., Mt. Airy, Philadelphia, Pa.
GARDNER, V. W.—from 531 E. 105th St. to 13706 Blenheim Rd., Cleveland, O.
GORDON, W. R.—from 985 Dewey Ave., Rochester, N. Y. to 33 Crescent Ave., Irondequot, N. Y.
GOSZTONYI, V. A.—from 3 Curry St., S. Charleston, W. Va. to 536 E. 3rd St., Bethlehem, Pa.
GRAHAM, A. K.—from Kirk-Latty Co. to 1619 Marlowe Ave., Lakewood, Ohio.
GRIFFITH, E. M.—from P. O. Box 75, Pittsburgh, Pa. to Universal Steel Co., Bridgeville, Pa.
GUNTERT, E. E.—from 505 Cutler Bldg., to 219 Post Ave., Rochester, N. Y.
HICKOX, DELOS—from Splitdorf Elec. Co. to 368 High St., Newark, N. J.
JOHNSTON, R. L.—from Acme Die Casting Corp. to Aluminum Die Casting Co., Brooklyn, N. Y.
LEDEBUR, G. A.—from 1102 E. 6th St. to General Elec. Co., Erie, Pa.
McDONOUGH, WM. D.—from Box 464, S. Charleston, W. Va. to R.F.D. No. 2, Reading, Pa.
McQUAID, H. W.—from Timken Roller Bearing Co. to P. O. Box 432, Canton, O.
MILLER, B. B.—from 5821 Pennsylvania Ave. to 5085 Iroquois, Detroit, Mich.
MITCHELL, W. M.—from 209 Kent Rd., Wynnewood, Pa. to 112 N. 34th St., Philadelphia, Pa.
NICHOLS, W. H.—from 44 Woerd Ave., Waltham, Mass. to Box 41 P.A.E., Exeter, N. H.
NORTH, J. H.—from Hawkridge Bros. Co., to Boston Athletic Assoc., Exeter St., Boston, Mass.
NORTON, O. G.—from Zenith Carburetor Co. to Henry Clay Hotel, Detroit.
OMALIA, JAMES—from 114 7th Ave., S. Charleston, W. Va. to Midland, Pa.
PFEIFFER, C. B.—from 2691 E. Jefferson Ave., Detroit, Mich. to Kirchen Machine & Tool Co., Lansing, Mich.
POLHEMUS, G. J.—from Ludlum Steel Co. to 1238 W. Washington Blvd., Chicago.

PUTNAM, A. H.—from 1710 E. 12th St. to 410 Perry Apts., Davenport, Iowa.
QUICK, G. W.—from Bureau of Standards, Washington, D. C. to Claredon, Va.
ROBERTS, J. H.—from Midvale Steel Ordnance Co., Philadelphia, Pa. to Electric Alloy Steel Co., Youngstown, Ohio.
ROHM, F. G.—from Universal Steel Co. to R. D. No. 3, Bridgeville, Pa.
ROOT, O. J.—from Root & Van Der Voort Eng. Co., E. Moline, Ill., to Eagle Rock, Calif.
STAMP, W. R.—from France Fire Eng. Co. to 828 Cedar Ave., Elmira, N. Y.
STENGER, E. P.—from 512 Park Ave., Harrison, O. to 3110 Imperial Ave., Cincinnati, O.
SYKES. C. J.—from H. G. Saal Co. to 2132 Lawrence Ave., Chicago, Ill.
TORSELL, C. T.—from 112 Dickey Ave. to Warren Iron & Steel Co., Warren, O.
TOWNE, T.—from 12 Platt St. to 32 W. 40th St., New York City.
WILLIS, R. E.—from 1401 David Whitney Bldg. to 6040 Woodward Ave., Detroit.
WOODWARD, A. F.—from 827 Main St., Charleston, W. Va., to 432 Hawkins St., Cincinnati, O.
YOUNGBLOOD, F. J.—from 755 Marlyn Rd. to 1317 Spruce St., Philadelphia, Pa.

MAIL RETURNED

BILLINGSLEY, J., 23 Euclid Avenue, Detroit, Mich.
BOYER, S. H., Studebaker Corporation, Detroit, Mich.
HOLLANDER, J. A. 459 Lawn Avenue, Cincinnati, Ohio.
MARRAN, JOHN S., 32 Rowsley St., Bridgeport, Conn.
PIERCE, FRED, (M-4), 2801 La Salle St., St. Louis, Mo.
TUEBER, CHAS. F., 1229 S. State St., Chicago, Ill.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

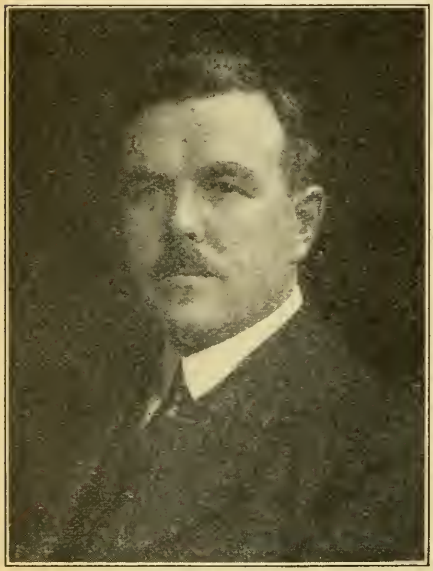
Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

TO THE MEMBERS OF ALL CHAPTERS AND ESPECIALLY TO THE MEMBERS OF ALL MEMBERSHIP COMMITTEES



D. H. Horne

GREETINGS: Permit us to introduce to you Mr. D. H. Horne, otherwise known as "Bert", who in his spare time represents the Standard Alloys Co. of Pittsburgh, and who has solved the mystery, if one ever existed, of how to secure Sustaining Memberships.

Not very long ago the Pittsburgh Chapter decided it needed a chairman of its Finance Committee who possessed the happy faculty of being able to increase the exchequer of the local chapter without making inroads upon his own personal bank account; further it was deemed advisable that inasmuch as a Sectional Meeting of the National Society was to be held in Pittsburgh on May 25 and 26 there should be a treasurer of the Finance Committee whose prerogative it would be to pay whatever expenses might be incurred by

the local chapter in extending true Pittsburgh hospitality to the visiting members and guests. Consequently Mr. Horne was honored with the appointment of Chairman of the Finance Committee, but he immediately discovered that he was chairman of a committee that did not have an excessive amount of the where-with all used in eradicating financial indebtedness.

"Bert" thought it advisable that his committee should be something other than one in name only and set about to prepare to meet future emergencies. The best plan that presented itself to the capable chairman was that of increasing the number of sustaining members of the Pittsburgh Chapter and thus obtain the increased revenue afforded to the local chapters by a recent ruling of the Board of Directors of the A. S. S. T. at their New York meeting which permits the local chapter to retain practically 75 per cent of the revenue provided from this class of membership.

Once a plan of action had been decided upon "Bert" got busy immediately, made several calls, wrote some letters and began to send in applications for sustaining memberships. The result of his activities during the past month brought 22 new sustaining members to the local chapter, as are listed under 'Sustaining Members' on page 23 of Transactions.

The Finance Committee no longer has cause to worry about the incurring of expenses for the Sectional Meeting as the Chairman of the Committee has solved the problem for them to their great satisfaction and admiration.

The activity of Mr. Horne is but an indication of what all the other chapters may do, providing a little thought, concentration and effort are given to the subject of Sustaining Memberships. All that was necessary in order to interest the manufacturing industries of the Pittsburgh district as to the desirability of supporting the local chaper and the National Society in their educational work was to have the matter presented to them for their consideration.

"Bert" has set the pace and is perfectly willing to give any information that any chapter may wish with reference to the "How" of his success and because of his great interest in the Society would be pleased to have anyone exceed his record of 22 sustaining memberships in one month.

HOW HIGH DOES YOUR CHAPTER STAND?

BELOW is printed the standing of your chapter with reference to the number of members it has. This list was compiled as of March 1. A new list will be published in the next issue of TRANSACTIONS with the standing as of April 1.

A very small amount of concentrated effort in securing new members will materially advance the position of your chapter as a large number of them are separated but by a few members only. Particular attention is called to the first six—the positions of Chicago, Detroit, Philadelphia, Cleveland, Pittsburgh and New York can easily be changed as they all have very close to the same number of members, so any special activity is sure to cause a rearrangement of their rank.

For increase of membership, Rockford has made a very commendable showing inasmuch as it was organized last December and since that time

has passed many of the older chapters until at the present it ranks in the fourteenth place.

Your interest in your chapter should be so strong that you should lend every endeavor to acquaint those who are or should be interested in the Society with the benefits of membership so that your chapter may take its proper position among the other chapters of the Society.

Following is the rank of the chapters on March 1:

1. Chicago
2. Detroit
3. Philadelphia
4. Cleveland
5. Pittsburgh
6. New York
7. Indianapolis
8. Hartford
9. Syracuse
10. Boston
11. Lehigh Valley
12. Milwaukee
13. North West
14. Rockford
15. Cincinnati
16. Tri City
17. St. Louis
18. Charleston
19. Springfield
20. Worcester
21. Providence
22. Schenectady
23. New Haven
24. Washington
25. Buffalo
26. Toronto
27. South Bend
28. Rochester
29. Bridgeport
30. Gary

PHILADELPHIA CHAPTER

The Philadelphia Chapter held one of its largest and most enthusiastic meetings on Friday evening, Feb. 24. This was the second annual "Big meeting," and it really was big, both from the standpoint of numbers and the high character of the addresses. A dinner in the Engineers Club, preceded the meeting, and was served to 52 members and guests. Later, when Chairman A. W. F. Green called for order, there were about 225 persons present to hear the fine program arranged for the meeting. The Chapter established the custom last year, of making a special occasion of the visit of the President of the Society

President F. P. Gilligan gave a most interesting paper, entitled, "Quality First in Material and Workmanship", illustrated in such a way as to bring out very clearly the salient points. This was the first opportunity the Chapter has had of meeting the National President, and they voiced their approval in no uncertain terms.

The meeting was particularly honored by the presence of Harry Brearley, of Sheffield, England, who was the guest of T. H. Nelson, general steel works manager of Henry Disston & Sons, Inc. Mr. Nelson also came from Sheffield. Mr. Brearley's name had been very prominently mentioned at the Chapter's January meeting by H. J. Stagg, thus the audience was anxious to hear him. While he said he had not come to talk, he made some interesting comments on President Gilligan's paper.

The Chapter's persistent efforts finally resulted in Dr. Mathews succumbing, and he gave an address entitled "What Is Steel"? His presentation of the subject was most scholarly. There are few men who know the answer to the question in his title, as well as Doctor Mathews, who is president of the Crucible Steel Co. of America. Both President Gilligan's and Dr. Mathews' papers will appear in a later issue of the TRANSACTIONS.

All business men in the vicinity of Philadelphia have a high regard for Richard Spillane, editor of the business section of the Philadelphia Publc Dedger. Mr. Spillane recently completed a national tour which brought him in contact with the leading industrialists of the country. He gave his views on the present situation in a highly entertaining and instructive manner. His remarks will be found elsewhere in this issue.

Any one of the speakers would have been a sufficient attraction, and

when there were four men of such caliber, it is not hard to find the reason for a large attendance. Among the guests were men from as far west as Altoona, as far south as Wilmington, and as far north as New York. The Lehigh Valley Chapter was represented by A. P. Spooner. This "Big Meeting" will be long remembered.

The Chapter's Membership Committee, under the guidance of George Richardson, has been working on a plan that has so far resulted in the addition of 17 new members. This has been accomplished largely through individual effort, supplemented by form letters, personally addressed and signed. Due to the fact that business conditions might be better, it is necessary to use different sales methods to obtain new members. President Gilligan, in his conference with the Executive Committee, before the meeting, emphasized the idea of applying a steady pressure rather than an intensive campaign. He stated that last year the Society had a growth of 18 per cent and he hoped that it could do as well this year.

The next meeting of the Chapter was on March 31 at the Engineers Club, at which time A. H. d'Arcambal gave an illustrated talk on "High Speed Steel". Mr. d'Arcambal is metallurgist of Pratt & Whitney Co., Hartford, Conn., and is an authority on the subject. E. H. Barker, of A. H. Wirz Co., Chester, Pa., also gave a paper on the "Local Hardening of Extruding Dies". This talk was scheduled for the January meeting but due to the lack of time after H. J. Stagg's paper, it had to be postponed.

ROCHESTER CHAPTER

S. W. Miller, president of the Rochester Welding Works, addressed the March meeting of the chapter which was held at the Engineers' Club on March 23. The subject of Mr. Miller's interesting paper was "Nonmetallic Impurities in Steel." Mr. Miller has a nation wide reputation for very excellent research work that he had done, and the local members felt very much pleased to have had Mr. Miller address them.

CINCINNATI CHAPTER

The regular March meeting of the Cincinnati Chapter was held on Friday, March 24, at the Ohio Mechanics Institute. Dr. J. Culver Hartzell presented an interesting paper on "The Crystallography of Iron, Its Fundamental Relation to Steels and Their Heat Treatment." In his address Dr. Hartzell gave some of the fundamentals of the crystallization of iron and steel. He also enlightened the members of the chapter on liquid and solid solutions and the effect of impurities in iron, the effect of heat treatment and the cause of fracture in steels.

SPRINGFIELD CHAPTER

The Springfield Chapter held its March meeting on Friday evening March 24 at the Chamber of Commerce building. The speaker of the evening was F. P. Gilligan of the Henry Souther Engineering Co., Hartford, and President of the Society who gave a talk on "What Happens to Steel When You Heat and Quench It". The talk was illustrated with a number of lantern slides showing the change in microstructure resulting from various treatments, photographs of actual pieces which failed in service through faulty treatment or material, methods of inspection, effect of various treatments recommended by the S. A. E. for carburized material, etc. The meeting was very largely attended and everyone enjoyed Mr. Gilligan's instructive presentation of the subject.

DETROIT CHAPTER

The first March meeting of the Detroit Chapter was held at the Board of Commerce on March 13. H. G. Freeland, metallurgist of the Hoover Steel Ball Co., Ann Arbor, Mich., presented a paper on "Ball Steel", treating the subject from the standpoint of the ball manufacturer including the inspection of the steel and the various stages of its fabrication. Mr. Freeland is a recognized authority on ball steel and his paper will be published in an early issue of the TRANSACTIONS together with the interesting discussion that took place at the meeting.

The second meeting of the month was held at the Elks' Club, on March 29 when an invitation was accepted by the chapter to be present and hear Charles E. Carpenter, of Philadelphia, who presented a talk on "Individualism vs. Socialism". Mr. Carpenter's reputation as a rapid fire speaker had preceded him and the turn-out that greeted him was a fine compliment to Mr. Carpenter and proved to be a worth while meeting.

NEW HAVEN CHAPTER

About 175 members and guests attended the meeting of the New Haven chapter on Wednesday evening, March 1 at the Geometric Tool Co. The excellent heat treating department of this company was in full operation and a practical demonstration took place under the direction of Major A. E. Bellis. Following the demonstration Frank P. Gilligan and W. H. Eisenman, National Secretary, addressed the members with reference to the "Activities of the Society", while Mr. Gilligan presented an illustrated paper on "Tool Steel" that was very favorably received. As an added attraction H. G. Hall, of R. Wallace & Sons Mfg. Co., presented his paper on "Stainless Steel" which he delivered before the New York Sectional meeting. Harry Brearley, of Sheffield, England, inventor of stainless steel, was present at the meeting.

NORTH WEST CHAPTER

The fifth lecture in the Educational Course being conducted by the Steel Treaters' Section, which is the Northwest Chapter of the American Society for Steel Treating, was held at the Club rooms Tuesday evening, Feb. 28. Dinner was served as usual at 6:30, and the business meeting commenced at 7:30. The subjects for the evening were "Malleable Iron, Its Production, Properties and Uses," by Sidney Horsley, superintendent of the Northern Malleable Iron Works, of St. Paul, and "Furnaces," by W. E. Johnston, Mahr Mfg. Co. This meeting followed closely the carefully thought out program for the course of lectures, so that the various topics are being developed as prearranged. Chairman O. E. Harder and the Executive Committee have been unusually successful in presenting a program which meets the requirements of the man who has had a technical education as well as the man whose experience is limited solely to his daily work in the shop. The briefs that are furnished with the lectures supply the members with a permanent record of each subject, so that at the close of the course they will have quite a voluminous file of educational matter of real value.

The regular meeting of this section, which would ordinarily have been held about the middle of March was postponed until Tuesday, March 28, when a joint meeting was held with the members of the Educational Course. The Executive Committee was fortunate in prevailing upon Prof. John F. Keller, president of Louis Institute, Chicago, to attend this

meeting and speak on the subject of "Forgings." As he was contemplating a visit to Milwaukee and later to Davenport, it required but little urging to induce him to include this city in his intinerary.

Mr. Keller has been trained in the mysteries of steel treating from a blacksmith, and is now one of the recognized authorities. He is a man who has had many years of active experience at the forge before taking up his technical studies, so that he possesses both a practical and a theoretical knowledge of the subject. He was professor of forging at Purdue University for fifteen years. He is past president of the Steel Treating Research Society, and as stated is now president of the Louis Institute of Chicago.

Dr. Charles A. Prosser, director of Dunwoody Institute, also addressed the members at this meeting on the subject of "Professional Spirit Among Steel Treaters."

PITTSBURGH CHAPTER

D. K. Bullens, of Philadelphia, addressed the Pittsburgh Chapter of the American Society for Steel Treating at its regular meeting on March 7. This meeting was held in the auditorium of the Bureau of Mines and the dinner preceding the meeting was attended by probably 80 members and guests. The total attendance for the lecture was well over 100. Mr. Bullens particularly stressed the human element factor in heating operations and the "One In and One Out", as he termed it, principally of securing continuous and uniformly heated parts.

Plans for the sectional meeting of the Society in Pittsburgh, May 25 and 26, are progressing very nicely as developed at the meeting of the Council on March 16. Probably one of the most encouraging bits of information received was that the Pittsburgh Chapter, through the efforts of D. H. Horne, has secured 22 new sustaining memberships.

At this council meeting T. D. Lynch, Westinghouse Electric & Mfg. Co., discussed the proposed standards specifications for the Society which the Standards Committee of the National Organization, of which he is chairman, is developing.

HARTFORD CHAPTER

The March meeting of the Hartford Chapter was held on March 9. The audience consisted of 90 members and guests. Among the visitors from other chapters and distant cities were Mr. Wedlake, of the Wilson-Maeulen Co., E. M. Converse, of the Dearborn Chemical Co., G. R. Brophy, of the General Electric Co., and Mr. Malone, of the Calorizing Co., of Pittsburgh. They were introduced to the audience together with four new members of the chapter, R. C. Baldwin of the Stanley Rule and Level Co., O. N. Ferry of the Waterbury Tool Co., A. G. Trapp of the Peck, Stowe, and Wilcox Co., and T. H. Platt of the Dearborn Chemical Co

G. R. Brophy gave an interesting talk on the subject of "Calite". His talk was based largely on his paper which appeared in the February TRANSACTIONS, but was new to many of those present and gave an opportunity for discussion by those who were unable to attend the New York Sectional meeting where the paper was first delivered.

The samples returned by competitors in the heat treatment contest were next exhibited, and the scleroscope and Rockwell hardness were determined on each in the meeting room. Owing to the large number of

tests which had to be made, it was not possible to finish the rating of each competitor. The final results and the winner of the prize, however, will be announced at the next meeting. If possible, the contest committee will tabulate the data obtained from the various tests, for publicaion at some future date.

The great variation in results obtained by the different competitors illustrated clearly that heat treatment is not a hit or miss proposition, but that success in obtaining desired physical properties requires close adherence to scientific methods. It was observed that the best results were obtained on chrome and nickel-chrome steels when a double treatment, that is, a normalizing quench plus a hardening quench, was applied. Double treatment also produced best refinement of the core in case hardened samples.

O. N. Ferry exhibited a cylinder barrel of a hydraulic variable speed gear, which was a small size replica of a 600-pound barrel used in controlling the speed of warships. On the 600-pound size, some difficulty was experienced in obtaining the desired hardness on case inner surfaces, which were required to be glass hard. High pressure jets of the quenching liquid were suggested, the jets to play in each hole of the carburized forging, also against the port face. It was also suggested that soft spots might be due to cementite networks produced by carburizing at an excessively high temperature. A temperature not in excess of 1650 degrees Fahr. was recommended for the carburizing operation.

As a matter of interest in connection with the heat treatment contest, one of the chapter members has discovered a new carburizing compound. His sample was exhibited at the meeting, and attention was called to the very fine case which was observed when the specimen was fractured. The audience was invited to try its luck at guessing the nature of the carburizing compound used. One guesser suggested that he had raided the barnyard, but it developed that it was really the hen coop that furnished the packing material.

ROCKFORD CHAPTER

The regular meeting of the chapter on Feb. 13 was held after the usual informal supper at the Nelson hotel. There were about 75 members present to hear National President F. P. Gilligan talk on "The Influence of Quality and of Workmanship on Material". Just preceding the address of President Gilligan, Mr. Birtchey, a guest, told the chapter something of his newly patented carburizing process which he hopes will be a time, labor and money saver for carburizers. He exhibited some interesting test pieces taken from a run made by Prof. J. F. Keller at Lewis Institute, Chicago.

President Gilligan was then introduced by Chairman Muehlemeyer and presented his very interesting paper. In the discussion which followed, high speed steel and grinding were the topics.

The regular March meeting of the Rockford Chapter was held on March 13 at the Nelson hotel. After an informal dinner the meeting was called to order at 8 p. m. The speaker of the evening was R. M. Smith, Mechanics Machine Co. and secretary of the chapter who chose "Pyrometers" as his subject. A lively discussion followed, and an enjoyable evening was spent by the large number in attendance.

WORCESTER CHAPTER

The February meeting was held in the assembly room of the Boy's Trade School on Feb. 28. C. A. McCune, welding engineer of the Paige

Steel & Wire Co., Bridgeport, lectured and showed an interesting moving picture film on "The Manufacture of Armco Ingot Iron, Welding Rods, and Electrodes". Mr. McCune showed samples of welding iron and made a thorough discussion of the entire subject. The National Secretary, W. H. Eisenman, was presented and outlined briefly the progress of the Society during the past year.

The annual meeting of the Worcester Chapter was held March 20 when President F. P. Gilligan, Dr. J. A. Mathews and Neil O'Hara were present and afforded the members a very profitable and interesting evening. The remarks of Chairman V. E. Hillman were as follows:

"Next month marks the anniversary of the Worcester Chapter. The idea of creating such an organization was conceived in the mind of my esteemed associate, Mr. Rogers. In fact, he has rendered invaluable aid in fostering the activities of the Society. His wide acquaintance in the steel industry, his association with men of affairs, and the contagious nature of his enthusiasm are intimately interwoven with the success of the Chapter.

"I wish to acknowledge my appreciation of the work accomplished by the Executive Committee. They made a generous contribution to the Chapter's early development. They offered material assistance in establishing its foundation. They tendered timely suggestions for furthering its objects. They responded to the call of the chairman. There was indeed, a genuine communion of interest among the handful of men who directed the affairs of the local chapter.

"The scope of the national organization is well known. Its aim is described as an educational movement to collect worth while ideas. Its deeper purpose, however, is to scatter, to extend, to circulate, 'that knowledge which does not guess, and skill of hand which does not err—these alone can turn waste into wealth and safeguard the standards of high efficiency.'

"Men of broad vision and foresight are in hearty accord with a project that diffuses ideas and interchanges experience and knowledge. The days of giant secrets are past, the mantle has been removed from industry, secrecy cast aside, egotism up-rooted, and self sufficiency has been displaced by a more sympathetic regard for the pursuits and passions of others.

"Two types of men may be in attendance at a chapter meeting; the parasite, who sucks sustenance from the brains of others and gives nothing in return, and the liberal mind who absorbs a fragment of knowledge and eagerly awaits the opportunity to impart an equal amount of intelligence to his fellow members. Current observation impells me to state that the Worcester Chapter is composed of men who belong to the generous minded class—men who are eager to rub elbows and exchange ideas for the betterment of their product. Guests who have been in attendance at our meetings have spoken of the quality of the discussions that usually follow the presentation of a paper.

"Admit, for so is the fact, that the local organization has been successful in its activities. We are now confronted with the responsibility of enlarging the framework that has been erected. This task may be accomplished readily by frequent elections. Your interest will be more secure, your society better governed, if you adopt the most simple and familiar portion of time applicable to an election, namely—one year. Where annual election ends, dissatisfaction begins. Every member should

familiarize himself with the activities of the Society. This information can best be obtained by holding office.

"Who should hold office? Any member whose merit may recommend him to the esteem and confidence of his associates; any member who possesses the capacity to discern and the ability to pursue the common good of the Chapter. He should be eligible for office. Wealth, station in life, professional standing, should not influence you in the choice of your officers. If the "Man at the Fire" is capable, elect him. Make the chapter democratic, the object of curiosity and conversation.

"I am eager to see the chapter advance, I am interested in its welfare. Hence, as retiring Chairman, I offer my remarks to the newly elected officers in a tentative manner."

The newly elected officers are: J. E. Rogers, chairman; and William Bacon, secretary-treasurer. The executive committee is composed of: G. C. McCormick, J. C. Spence, P. H. Knowles, and V. E. Hillman.

SYRACUSE CHAPTER

The March meeting of the Chapter was held at Yates hotel on March 4 and consisted of a round table discussion of troubles. It was not supposed that as many troubles existed in Syracuse as were presented at the meeting, however, each one brought forth a very interesting discussion and suggestions resulted for the elimination of the difficulties.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held a fine meeting on March 14 when O. F. Luckenbach presented an exceptionally fine paper on "Drop Forgings" while B. F. Shepherd presented an equally interesting paper on "Carburizing". The meeting was held at the Easton Public Library and was very largely attended.

RHODE ISLAND CHAPTER

The Rhode Island Chapter held a meeting on Wednesday, March 8, at the Providence Engineering Society rooms when President F. P. Gilligan paid his annual visit to the chapter. About 100 were in attendance and highly appreciated Mr. Gilligan's exposition of his subject. A buffet luncheon and smokes were served at the close of the discussion.

MILWAUKEE CHAPTER

The Milwaukee Chapter held a very interesting meeting in the Hotel Medford on Monday evening, March 27, when Prof. J. F. Keller, of Lewis Institute, Chicago, spoke on the subject of "Why Steel Warps". Professor Keller had a number of interesting proofs with reference to the working of steel. A large audience greeted Professor Keller and felt highly repaid for their attendance. H. G. Lloyd, 611 Majestic building, has been elected Secretary-Treasurer of the Milwaukee Chapter. Mr. Lloyd brings to the office a wide acquaintanceship with the steel treating industry of this vicinity as well as a wide experience in secretarial duties. The Chapter is to be congratulated on Mr. Lloyd's acceptance of the position.

ST. LOUIS CHAPTER

The March meeting of the St. Louis chapter was held at the Engineers' Club on March 10. About 75 were present to see the motion picture films on the "Manufacture of American Tool Steel" through the courtesy of the Atlas Crucible Steel Co., Dunkirk, N. Y., but at the last

minute the film was damaged at the factory and could not be shown. The meeting was turned into a round table discussion of tool steels and heat treating problems and while there was considerable disappointment because of the failure of the films to arrive, nevertheless, the meeting proved to be very successful.

WASHINGTON CHAPTER

On March 22 one of the most interesting meetings of the year was held by the Washington Chapter, at which a general discussion of the selection, heat treatment, inspection and testing of automotive steels was carried on in the presence of about 40 to 50 members and guests. Beginning with the application, treatment and properties of various nickel-chromium steels and followed by an interesting presentation by one of the members of the chapter relating to characteristics of spring steels, the discussion finally turned to the question of gases in metals, melting practice and carburizing.

Among those who participated in various phases of the discussion were P. E. McKinney, and Jerome Strauss, Washington Navy Yard; J. S. Vanick and H. J. French, Bureau of Standards, and W. H. White, secretary-treasurer of the Charleston Chapter.

Preceding this very lively session, lasting for more than 2 hours, the usual dinner was held at the Harrington Hotel. These have become one of the interesting and important features of the regular meetings, and during the past 4 months there has been an average attendance of about 16.

Commercial Items of Interest

UNDER the joint sponsorship of the Grinding Wheel Manufacturers Association of the United States and Canada and the International Association of Industrial Accident Boards and Commissions, a sectional committee has been organized for formulating a safety code for abrasive wheels. The code prepared by this committee and approved by the sponsors has been approved as a tentative American standard by the American Engineering Standards Committee. The code contains rules and specifications considered necessary to insure safety in the use of abrasive wheels operating at speeds in excess of 2000 surface feet per minute. It consists of sections dealing with scope, types of protection devices, storage and inspection of wheels, general machine requirements, protection hoods, work rests, protection of wheels, flanges, mounting, speeds, operating rules and general data. It is well illustrated.

Copies of the code may be secured from the American Engineering Standards Committee, 29 West Thirty-ninth street, New York, at 10 cents each.

The Colonial Steel Co., Pittsburgh, has recently purchased ground at 2121 St. Clair avenue, Cleveland, and will erect at once a brick warehouse to be used for the storage and sale of the crucible and open-hearth tool steel made by that company. In addition, this warehouse will contain furnaces and equipment for heat treating steel with a view to assisting customers in working out problems of this kind and for investigating the best methods of treatment.

Burning Liquid Fuel is the title of a recent book by William Newton Best, published by the U. P. C. Book Co., Inc., New York. The selling price is $5.00. This book which has 342 pages, contains a wealth of material on burners, furnaces and various oil burning installations. It is a practical treatise on the perfect combustion of oils and tars, giving analyses, calorific values and heating temperatures of various gravities of fuel. Information is given on the design and proper installation of equipment for all classes of service. In an effort to make the volume as clear and simple as possible some 316 photographs and sketches are reproduced. Doctor Best is a pioneer in the development of liquid fuel and has followed its rapid expansion in recent years, thus he is recognized as an authority upon the subject.

The Bureau of Standards, Washington, is preparing a summary of the data obtained on the various carbon and alloy steels which have been tested in the metallurgical laboratories of the bureau. This summary will include the effects of normalizing rolled low carbon steel, the effects of 1.25 per cent of manganese, the presence of 5 per cent

cobalt, the addition of 0.4 per cent molybdenum to carbon-chromium steel, and the effect of various heat treatments on their properties. Progress has been made also in determining the effect of time annealing at blue heat on the properties of cold rolled boiler plate.

In pamphlet No. 168, recently issued by E. Leitz, Inc., New York, microscopes and pertinent equipment is described. This includes several types of lamps for illuminating the specimens. The manufacturer introduces a new research microscope equipped with the double eyepiece, thereby eliminating eye strain and fatigue.

Hugh M. Henton, formerly of Case School of Applied Science, Cleveland, has opened an office as consulting engineer in metallurgy and metallography, in the National City building, Cleveland.

The Surface Combustion Co., 366 Gerard avenue, New York, announces that it has ready for distribution Bulletin No. 3D on its low pressure air-gas inspirators. These inspirators are designed so as to be readily applicable to any make of gas furnace.

A new office has been opened at 1011 Majestic building, Milwaukee, by the Armstrong Cork & Insulation Co., Pittsburgh, with Hugh Krampe in charge. It will serve eastern Wisconsin and the upper peninsula of Michigan. The Denver office has been re-established at 1875 Gaylor street under Alex Callow.

James E. McKenny, for the past year superintendent of the Standard Spring Co., Cleveland, has resigned and returned to his former home in Worcester, Mass. Before going to Cleveland he was located in Youngstown, O. Mr. McKenny is a former superintendent of the National works of the Wickwire Spencer Steel Corp., Worcester, and at one time was production manager for the former Morgan Spring Co. of that city, now the Morgan works of the Wickwire Spencer Steel Corp.

Robert C. Stanley, formerly first vice president, recently has been elected president of the International Nickel Co., Bayonne, N. J. Mr. Stanley will effect a reorganization of personnel, involving as its chief feature a new department of development and research with headquarters at 67 Wall street, New York. This department will be under the direction of A. J. Wadhams, as manager and associated with him will be Dr. Paul D. Merica, director of research. Mr. Wadhams has been manager of the large Bayonne refinery of the company and has for years been in direct charge of the manufacture of the company's products.

F. G. Davis, who has represented the Atlas Crucible Steel Co. in the Detroit district for the past three years, has resigned effective April 1 to accept the position of district manager of sales in the Detroit district

(*Continued on Page* 651)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST—Chemist or Superintendent of Heat Treatment. Technical graduate. Extensive experience with some of the largest companies in the country, also steel mill experience. Heat treatment, tool hardening, annealing, pyrometry, chemical analysis, physical testing, metallography, magnet testing, tool testing, investigation of trouble and research. Age 26. Reasonable salary desired. Eastern location preferred. 2-15.

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

ASSISTANT—METALLURGIST—Technical graduate. Specialized on Pyrometer maintenance and installation. Five years experience in heat treating department and laboratory of several large automobile parts manufacturing companies. Experienced in handling of men. (Write for detailed experience.) Location preferred Cleveland. Salary desired $175.00. Address 2-25

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING, Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U. S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

FOREMAN OR INSTRUCTOR—Nine years instructor forge work, College Cornell University; four years foreman toolsmith and steel treater of large ship-building corporation. Thoroughly experienced in all classes of steel. Wages reasonable. Location preferred Ohio, Massachusetts, New York, Pennsylvania, and Connecticut. 2-5

STEEL EXPERT—Heat treatment, metallurgy. A graduate in chemistry and iron and steel manufacture. Six years laboratory experience. Desire position in production department. Can make good. Present salary ($3000.00) Ordnance man, Navy Department. Will consider ($2000.00) as a start if there are good prospects. Address 3-10

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths Best of references. Reasonable salary. Address 3-15

CHEMIST OR ASSISTANT TO CHIEF METALLURGIST: Technically trained. Practically experienced in chemical and physical analysis, pyrometry general heat treating, foundry control, shop work and methods. Able to investigate trouble and handle same. Michigan or adjacent territory preferred. Answer 3-20

TOOL HARDENER OR FOREMAN—30 years earnest effort in tool forging and tool hardening with extensive high speed steel experience. Can offer efficient operation or supervision. Exceptionally successful in eliminating scrap—Excellent references. Location immaterial. wages desired $50.00 per week. Address 3-40

SALES ENGINEER—Thorough metallurgical training and experienced salesman. At present employed but desires change. Wide acquaintance New York, New England and Canada. Basic knowledge foreign markets and can produce. Age 28. Married. Address 4-5.

FOREMAN HEAT TREATMENT—16 Years experience on armor plate gun forgings and all kinds of heavy forgings and castings; carburizing, research, testing and experimental work including design operation and erection of all types of heat treating furnaces. Age 32. Married. Address 3-5.

METALLURGIST—College graduate, at present metallurgist with prominent automotive concern, three years experience in general heat-treating, case hardening pyrometry, microscopic examination and chemical analysis. 2-10.

CHEMIST-METALLURGIST—Experienced in making steel castings, all processes. Am a practical foundry man, steel blower, and chill roll maker. Have been Supt. of large foundry. Best of References. Age 40. Married. Address 3-2.

METALLURGIST OR CHEMIST—Graduate of Ohio State. Extensive experience covering heat treatment, case hardening, pyrometry, chemical analysis, metallography, and investigation of tool troubles. Best of recommendations. No preference as to location. Address: 4-50.

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

FOREMAN: 30 years practical experience in heat treating, forging tool hardening, carbonizing. 5 years as foreman of heat treating. Location preferred in Pennsylvania, New Jersey, or Maryland. Salary desired $200 per month. Address 9-3.

HEAT TREATING DEPARTMENT—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary $150.00. Cleveland location preferred. Address 4-10.

METALLURGIST—Eight years experience in research, metallography, heat treatment, complaint and service work; High speed, tool steel and cast cutter work. Address 3-30

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 12-10.

POSITIONS OPEN

WANTED—Young college graduate with one or two years practical experience in physical metallurgy to carry out physical tests and micro examination with a government bureau. Entrance salary $1800 per annum. Position offers excellent opportunity to become familiar with certain phases of physical metallurgy of great practical value. Address 4-32.

COMMERCIAL HEAT TREATING PLANT—A young man not afraid of work who is willing to give his best efforts so that he can advance in confidence of the employer and ultimately attain a position of responsibility. Experience desirable, but not necessary. Plant located in Cleveland. Address 4-50

ADVERTISING SOLICITOR—A well known publication desires an experienced steel salesman to solicit specialized advertising. Salary and commission. Headquarters will be in New York, but unlimited as to territory. Experienced in soliciting advertising not necessary. Address 4-60

STEEL SALESMAN—To cover Northern Ohio. Must have had selling experience and thoroughly familiar with high speed and carbon tool steels. An excellent opening for someone who can produce results. Address 3-10.

A well known steel firm desires tool steel salesman to work out of Cleveland office. Would consider only a thoroughly experienced man. Address 4-44.

(*Continued from Page 649*)

for the Electric Alloy Steel Co., Youngstown, O. Mr. Davis will occupy temporary offices in room 1716 Ford building, Detroit. This company is installing a complete warehouse stock in Detroit, and the district offices will be moved to the new warehouse as soon as arrangements are completed.

Standardization work in Japan recently was given a great impetus by the organization of the Japanese Engineering Standards Committee. The main function of this committee is to serve as a bureau for solving and initiating problems involving engineering standardization. The committee consists of 70 members presided over by the minister of the department of agriculture and commerce acting as president, and a vice president, who is elected or appointed. The details of the work are handled by seven secretaries who are engineers of the government departments of agriculture and commerce, communications, railways, military engineers and naval engineers. The work is being pushed with vigor, investigations already being under way on metals, woods, bricks, screws, electric wires and electric motors. In Norway a national standardization committee has been organized by the Federation of Norwegian Industries. There are now national standardizing bodies in the following fourteen countries: Austria, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Holland, Italy, Japan, Norway, Sweden, Switzerland and the United States.

At the adjourned annual meeting of the American Engineering Standards Committee held in New York recently Albert W. Whitney, a repre-

sentative of the National Safety Council was elected chairman, and George C. Stone, a representative of the American Institute of Mining and Metallurgical Engineers, was re-elected vice-chairman. Mr. Whitney is associate general manager of the National Bureau of Casualty and Surety Underwriters.

L. S. Cope, formerly metallurgical engineer for the Hoover Steel Ball Co., Ann Arbor, Mich., has taken charge of the metallurgical work of the National Screw & Tack Co., and the Cleveland Motorcycle Mfg. Co., both of which are located in Cleveland.

Samuel R. Robinson has resigned as foundry superintendent of the Sandusky Foundry & Machine Co., Sandusky, O., to accept a position as metallurgist of the Lorain Foundry Co., Lorain, O. From 1918 to 1921 Mr. Robinson was metallurgist for the Philadelphia Roll & Machine Co., Philadelphia, and prior to that he was for 11 years metallurgist for the Duquesne Steel Foundry Co., Coraopolis, Pa.

The Society of Automotive Engineers has just issued the announcement that its 1922 summer meeting will be held at White Sulphur Springs, W. Va. The date selected is June 20-24. Plans are being made for the customary sports, entertainment and technical programs.

The address of the St. Louis office of the Chicago Flexible Shaft Co., Chicago, has been changed from the Railway Exchange building to 420 Wainwright building.

Keith Reeves Rodney, formerly metallurgist of the Bullard Machine Tool Co., Bridgeport, Conn. and first chairman of the Bridgeport Chapter of the American Society for Steel Treating, is with the process and development department of the American Chain Co. and is at the present time doing some important work at the plant of the Highland Iron & Steel Co., Terre Haute, Ind.

Boston offices at 79 Milk street, have been opened by the Celite Products Co.

The Gas Combustion Co., Pittsburgh, will remove its offices from the Union Arcade building, on or about April 1.

A number of changes have been made recently in the sales organization of the Celite Products Co., several new offices being opened. Branch offices have been established in Boston, Buffalo, Cincinnati and Minneapolis. F. W. Emerson has been placed in charge of the Boston office, W. D. Van Arnam is district manager of the Buffalo territory, L. M. Lindsey is in charge of the Cincinnati office and E. R. LaBelle is at Minneapolis. A

(*Concluded on Page* 34, *Adv. Sec.*)

TRANSACTIONS
of the
American Society for Steel Treating

Vol. II Cleveland, May 1922 No. 8

PITTSBURGH SECTIONAL MEETING ARRANGEMENTS

THE WILLIAM PENN Hotel will be the headquarters for the Pittsburgh Sectional meeting to be held May 25 to 27. Arrangements have been made by the committees in charge, whereby a limited number of rooms will be available at the hotel. Due to the fact that there is another large convention being held in Pittsburgh at this same time it is highly important that all those who are planning on attending this meeting, make their reservations without delay. It is suggested that requests for reservations be sent either to the hotel or to W. A. Buechner, 501 Manufacturers building, Pittsburgh, or D. H. Horne, Standard Alloys Co., Pittsburgh.

The members of the Pittsburgh Chapter are bending every effort to make this meeting an unqualified success. All of the arrangements have been made for carrying through this meeting. The program of papers, plant visitation and entertainment clearly indicate that the Pittsburgh meeting will not be second to the New York Sectional meeting held in March.

Four of the papers to be presented are published in this issue of the TRANSACTIONS. Discussion of these papers is invited and it is hoped that good lively comment will follow each of the papers presented. If for any reason a member is unable to attend the meeting, a written discussion of any or all of the papers would be appreciated by the committee in charge, and can be addressed to W. J. Merten, 416 Lang avenue, Pittsburgh.

The program for the meeting is as follows:

Thursday, May 25

11 a. m. to 1 p. m.—Auditorium, Bureau of Mines.

Informal gathering and registration of out-of-town members and guests. In charge of W. H. Eisenman, National Secretary, assisted by Messrs. Horne, Phillips, and Cook.

1:30 p. m. to 4:30 p. m.—Auditorium, Bureau of Mines.

Address of welcome, by Chairman of Pittsburgh Chapter.
Response by National President, F. P. Gilligan.
Technical Session presided over by Past Chairman of Pittsburgh Chapter.
Papers by:

Professor McIntosh, Carnegie Institute of Technology, "Fiber in Steel and Iron".
W. B. Crowe, metallurgist, Carnegie Steel Company, "Mass Influence on Heat Treating".
John M. Lessells, Westinghouse Electric & Mfg. Co., East Pittsburgh, "Impact Tests".

7:00 p. m.—University Club—Banquet.

Addresses and music relayed over KDKA, Westinghouse Radiophone station.
Toastmaster—G. H. Neilson, president, Braeburn Steel Co. and past president,

Western Pennsylvania Engineers Society.
Speakers—Doctor Bowman, chancellor, University of Pittsburgh; Dr. J. A. Mathews, president, Crucible Steel Co. of America; Prof. F. Crabtree, chairman, American Institute of Mining and Metallurgical Engineers, Pittsburgh Division; and vice chairman, Western Pennsylvania Engineers Society. "History of Metallography and Heat Treatment of Iron and Steel".
Followed by impromptu speeches by guests representing prominent local industries.
Music by Greater Pittsburgh Quartet.

Friday, May 26

9:00 a. m. to 12:00 m.
Assembly at Schenley Hotel to visit steel mills and manufacturing plants.

1:30 p. m. to 4:30 p. m.—Auditorium, Bureau of Mines.
Technical Session—Presided over by Chairman of visiting section.
Papers by:
A. M. Cox, Pres. and Treasurer, Pittsburgh Commercial Heat Treating Co., Pittsburgh.
J. A. Succop, Heppenstall Forge & Knife Co., "The Importance of Properly Heated and Cooling Steel".
Mr. Smith, Union Spring & Manufacturing Co., New Kensington, Pa., "Manufacture of Springs".
Mr. Marcus A. Grossman, Electric Alloy Steel Co., Youngstown, O., "Shrinkage of High Speed Steels".

7:30 p. m. to 11:00 p. m.—Auditorium and Cafeteria, Bureau of Mines.
Open-Hearth Furnace Film—American Rolling Mill Company.
Smoker, in charge of Entertainment Committee.

Saturday, May 27

10.00 a. m.—Auditorium, Bureau of Mines.
Directors meeting.

8:00 p. m.
Carnegie Institute of Technology, School of Dramatic Arts. Little Theater play by School of Dramatic Arts.

HOTEL RATES FOR PITTSBURGH MEETING

BELOW are given the hotel room rates for the William Penn Hotel, which has been selected as the headquarters during the Pittsburgh Sectional meeting, May 25 to 27. The rates are as follows:

Court rooms, single with shower bath	$5.00 per day
Court rooms, single with tub bath	$5.00—$5.50 per day
Court rooms, double with shower bath	$6.50 per day
Court rooms, double with tub bath	$7.00 per day
Court rooms, double with twin beds, bath	$7.50 per day
Outside rooms, single with tub bath	$6.00—$7.00 per day
Outside rooms, double with tub bath	$8.00—$9.00 per day
Outside Rooms, double with twin beds, bath	$9.00—$10.00—$11.00 per day

NEW YORK SECTIONAL MEETING IS GREAT SUCCESS

NO DOUBT can exist as to the complete success of the New York Sectional Meeting which was held at the Hotel McAlpine, Friday, March 3. This was the Society's first effort to hold a sectional meeting and upon its success or failure depended more or less the policy of the Society in future meetings of the same kind. The registration totaled approximately 200 with 14 eastern and New England chapters being represented. The purpose of the Society is to hold such meetings in different portions of the country which would serve to bring the membership of

that locality into closer touch with one another and to afford to those, that had not attended the annual Conventions some of the advantages that accrue from a general meeting of the Society.

The opening session was held on Friday afternoon by an address of welcome by George L. Norris, chairman of the New York Chapter. Following this the chairmanship of the meeting was turned over to Irving H. Cowdrey, chairman of the Boston Chapter, who introduced the five speakers. The technical papers presented and their authors were as follows: "New Development on the Influence of Mass in Heat Treatment," by E. J. Janitzky, metallurgical engineer, Illinois Steel Co., South Chicago, Ill.; "Calite—A New Heat Resisting Alloy," by G. R. Brophy, metallurgist, research laboratory, General Electric Co., Schenectady, N. Y.; "Stainless Steel in Cutlery Use," by R. G. Hall, research engineer, R. Wallace & Sons Mfg. Co., Wallingford, Conn.; "Cold Headed Bolts—Their Metallography and Heat Treatment," by V. E. Hillman, metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.; and "The Magnetic Testing of Small Case Hardened Chain," by A. V. De Forest, metallurgist, American Chain Co., Bridgeport, Conn. The papers of Mr. Janitzky, Mr. Brophy, Mr. Hillman and Mr. De Forest appeared in the February issue of TRANSACTIONS while the paper of Mr. Hall together with the discussions for all the papers were published in April. Mr. De Forest gave an actual demonstration of the magnetic chain testing process showing the results which could be obtained regarding the proper care required for automobile skid chains.

In the evening about 100 attended the informal dinner at the Yates Hotel, where the menu consisted of water-quenched celery, oil-tempered olives, case-hardened tenderloin beef, sorbitic peas, over-heated potatoes, etc. The second technical session was held Friday evening at the Hotel McAlpine with A. W. F. Green, chairman of the Philadelphia Chapter as the chairman. For a few minutes the meeting was turned over to the National President F. P. Gilligan, who presented an engraved certificate of honorary membership to Dr. John A. Mathews, president of the Crucible Steel Co. of America. Doctor Mathews was elected to this honor by the Board of Directors meeting at the Indianapolis Convention. The recipient is widely known for his work in developing and heat treating alloy steels as well as his pioneer work in connection with the manufacture of electric steel. Doctor Mathews accepted the certificate with a brief speech of appreciation.

The first technical paper, "Perfecting a Drop Forging" was presented by J. H. G. Williams, assistant works manager, Billings & Spencer, Hartford, Conn. This paper appeared in full in the February issue of TRANSACTIONS but the discussion was in the April issue. At the conclusion of Mr. Williams' paper, the meeting was turned over to National Secretary W. H. Eisenman, who reviewed extensively the events leading to the amalgamation of the two heat treating societies into the present organization and stressed particularly the leading part which Lt. Col. A. E. White had played, later becoming the first National President of the Society. Then calling Colonel White to the front, Mr. Eisenman, on behalf of the entire society presented him with a mahogany chest of sterling silverware.

In part Mr. Eisenman's words were as follows: "Colonel White, this chest of sterling is presented to you for a particular reason. Sterling

—because it represents the character of the recipient, sterling because it represents the foundation work which he has so well laid and which is shown in the progress and success our Society has made. Colonel, I present you this key, and may it unlock this chest and give to you as much satisfaction as it gives to us pleasure in the presentation of it, and may you consider it as a mark of our undying esteem and high regard for you and your work." Colonel White was taken entirely by surprise. With a few brief remarks he assured the Society of his heartfelt appreciation.

The final paper on the program was "The Manufacture of Steel", by B. H. De Long, metallurgist, Carpenter Steel Co., Reading, Pa. This paper was highly illustrated and showed the equipment for making high grade tool steels by the open-hearth, electric and crucible processes.

BOARD OF DIRECTORS NAMES EDITOR FOR TRANSACTIONS

Ray T. Bayless

IT IS with pleasure that the Board of Directors is able to announce the appointment of Ray T. Bayless as full time editor of the TRANSACTIONS. The Board has been considering this matter for some time and it now feels that the Society requires and can support the services of an editor devoting his entire time to the publication. It is the aim and purpose of the national officers to have the TRANSACTIONS stand out prominently as an educational publication and with this in view, a definite constructive program will be developed that will serve the needs respectively of the practical steel treater and forger, the technically trained man and the executive who exercises general oversight and direction of both practical and technical groups. It is expected that the editor eventually will be brought in close contact with the officers and outstanding members of the various chapters of the Society and that he will be able to correlate some of the educational activities of the various chapters so that ultimately the TRANSACTIONS will offer a more intensive and continuous program along educational lines than has heretofore been possible.

In extending this work, subjects of interest to the technical member will not be overlooked, but on the other hand it is hoped that it will be possible to establish closer relations with other metallurgical societies in this country and abroad, and to keep our members in intimate touch with developments of interest in the steel treating world at large.

Mr. Bayless graduated from the University of Michigan with the degree of Bachelor of Chemical Engineering. During his university work he specialized in metallurgy and metallography and acted as student assistant during his junior and senior years.

Mr. Bayless was born and raised in Detroit and has had extensive experience in the metallurgical profession. Upon graduation he was assistant analytical chemist with the Michigan Smelting and Refining Co., Detroit, after which he become assistant analytical chemist with the General Motors Co. at its Detroit laboratory.

For about two years Mr. Bayless was assistant chief chemist and metallurgist with the Chalmers Motor Co., being promoted to chief chemist and metallurgist of the Saxon Motor Car Corp., remaining with that company until its plant was destroyed by fire.

During the war, Mr. Bayless was supervisor of tests for the United States Army Ordnance Department, Cleveland district, having supervision of all tests of materials used in the production of ordnance in that district. One hundred direct assistants were under his supervision.

At the close of the war he become associated with the James H. Herron Co., engineers and was in charge of all metallurgical problems having under his supervision the metallographical, physical and heat treatment laboratories.

Mr. Bayless brings to the TRANSACTIONS an extensive knowledge of metallurgy from both the practical and theoretical standpoint and will give his best efforts in making the publication of greater service to the membership.

TREASURER SUBMITS FINANCIAL STATEMENT

THE accompanying report of the auditors shows the history of the financial transactions of The American Society for Steel Treating for the first full year of its operation. Attention is called to the fact, that the total support given the local chapters is not shown by the income and expense statment. This is because during the greater part of the year dues were collected by the chapters who deducted their 35 per cent before remitting to the National Office. The total financial support given the Chapters for the year was $9,700.00

It will be noted that the income and expense shown for the Philadelphia Convention represent deferred collections and expenses which were carried over from the year 1920.

The most favorable time for closing the books of the Society having been found to be Jan. 1, the Finance Committee has designated the calendar year as the fiscal year of the Society, so far as its financial transactions are concerned. The report appears in full on the following page.

Signed

J. V. EMMONS,
Treasurer

AMERICAN SOCIETY FOR STEEL TREATING INCOME AND EXPENSE STATEMENT, YEAR 1921

INCOME

Advertising		$20,147.16	
Membership dues (exclusive of 35 per cent portion retained by chapters)	$21,732.66		
Less refund to local chapters	2,489.91	19,242.75	
Indianapolis convention (1921)	14,549.65		
Less refunds to exhibitors	645.40	13,904.25	
Philadelphia convention (1920)		1,953.72	
Transaction sales		701.07	
Miscellaneous income		622.61	
Interest and discounts		387.52	$56,959.08

EXPENSES

Transactions	17,366.70	
Secretary's office	9,807.62	
President's office	1,941.48	
Treasurer's office	895.00	
Directors' expense	661.57	
National committees	329.42	
Indianapolis convention (1921)	13,697.81	
Philadelphia convention (1920)	1,201.32	
Bad debts	1,614.71	
Miscellaneous expense	849.85	
Discounts allowed	488.36	48,853.84
Excess of income over expenses		8,105.24

BALANCE SHEET

Dec. 31, 1921

ASSETS

Current cash	$1,635.14
Cash and securities held as reserve for dues paid in advance	9,500.00
Accounts receivable	4,202.42
Furniture and fixtures	1,183.34
	$16,520.90

LIABILITIES

Accounts payable			$640.16
Reserve for dues paid in advance			9,500.00
Reserve for past due and doubtful accounts			800.00
Surplus Dec. 31, 1920		$7,958.83	
Excess of income for year		8,105.24	
		$16,064.07	
Less—			
Depreciation furniture and fixtures	$983.33		
Reserve for dues	9,500.00	10,483.33	
Surplus Dec. 31, 1921			5,580.74
			$16,520.90

CERTIFICATE

We have made an audit of the books of account and record of the American Society for Steel Treating and, in our opinion, the above Balance Sheet and Income and Expense Statement correctly present its financial status at Dec. 31, 1921, and a history of its financial transactions for the period under review, basing the income from dues upon cash receipts and other income upon accruals.

Respectfully submitted,

NAU, RUSK & SWEARINGEN,

Certified Public Accountants.

A DISCUSSION OF IMPACT TESTING METHODS AND THE RESULTS OBTAINED

By John M. Lessells

DUE to the advent of the automobile and aircraft engines, and the high working stresses used in service, the heat treatment of steels has become an applied science. The quality of the heat treated product must be determined by recognized and accepted physical tests, and these must be in some measure welcome to the heat treater and the steel manufacturer. If it can be established that some new test shows up characteristics in a heat treated steel which the accepted and more or less conventional tests do not show, then this test should be favorably regarded by all who desire to get the best from their materials. Since the impact test seems to be in this catagory, it is proposed to present a few more or less familiar facts on this method or testing, together with certain conclusions, for consideration and discussion.

It has been said that the impact test is a new one, but this is literally not correct, since it has been used for a considerable time as an acceptance test in certain European specifications; but since it is not generally adopted in this

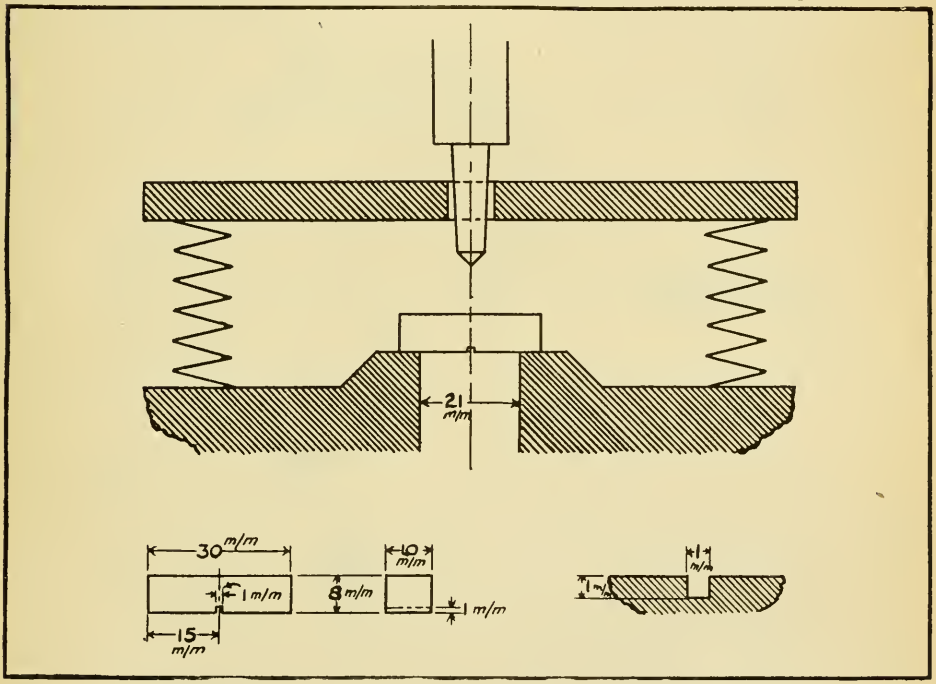


Fig. 1—Arrangement of Fremont impact testing machine with sketch of test specimen shown below

country, it can be so considered. A committee of the American Society for Testing Materials is at present working on some form of test suitable for the United States requirements.

There are numerous forms of impact testing machines, but it is only proposed to review a few of them: namely 1. Fremont, 2. Charpy, 3. Izod,

A paper to be presented at the Pittsburgh Sectional meeting, May 25-27. The author, John M. Lessells, is connected with the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

and 4. Stanton. Each of these machines, named after the inventor, use a notched test specimen. Therefore, these tests might be more aptly called "notched bar tests." The Stanton test is really a repeated impact test although it has been given a place in this discussion.

The Fremont test requires a test specimen which is 30 millimeters long having a cross section of 8 by 10 millimeters. It is notched on the broad side 1 millimeter deep and 1 millimeter wide. The test piece is laid on supports 21 millimeters apart with the notch on the underside and struck a blow with a falling tup midway between the supports. The difference between the energy before and after the fracture gives the amount of energy necessary for fracturing the test specimen. In Fig. 1 is shown a sketch of the arrangement of this machine and a sketch of the test piece employed. The weight of the tup, which falls from a height of 4 meters is 10 or 15 kilograms. It will be noted that a machine of this kind requires considerable height above the floor level, but possesses the advantage of having a high speed of impact.

The Charpy test requires a test specimen which is 55 millimeters long, having a cross section of 10 by 10 millimeters. It is notched in the center

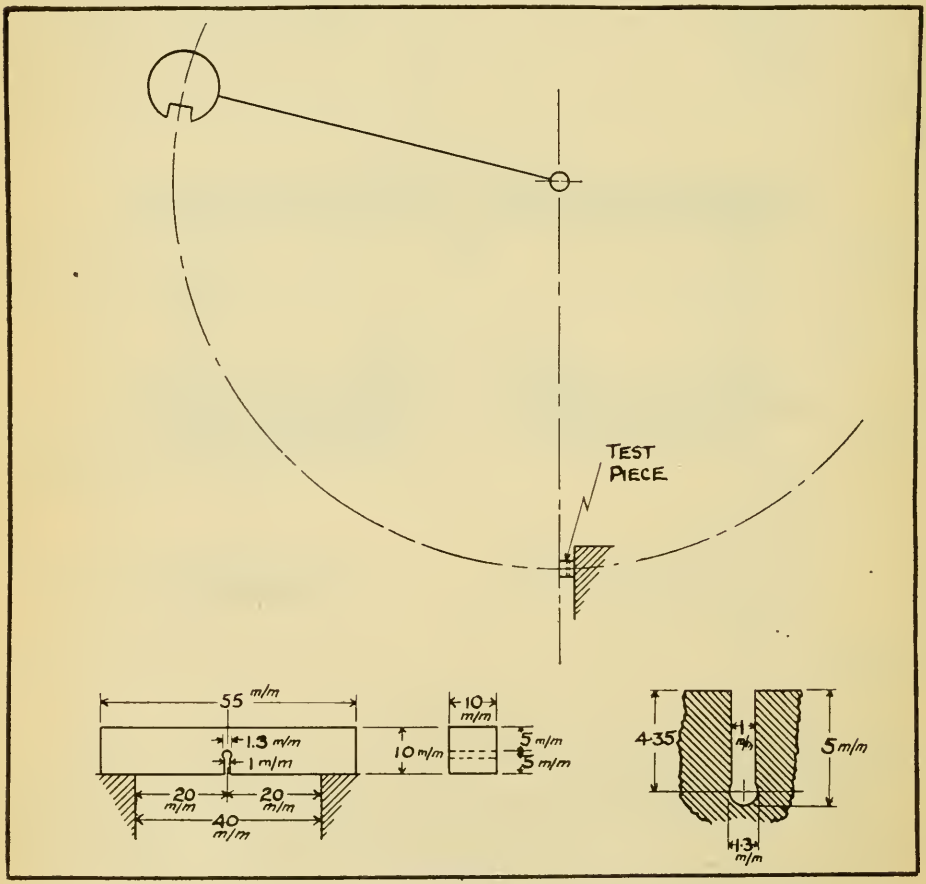


Fig. 2—Arrangement of Charpy impact testing machine with sketch of test specimen shown below

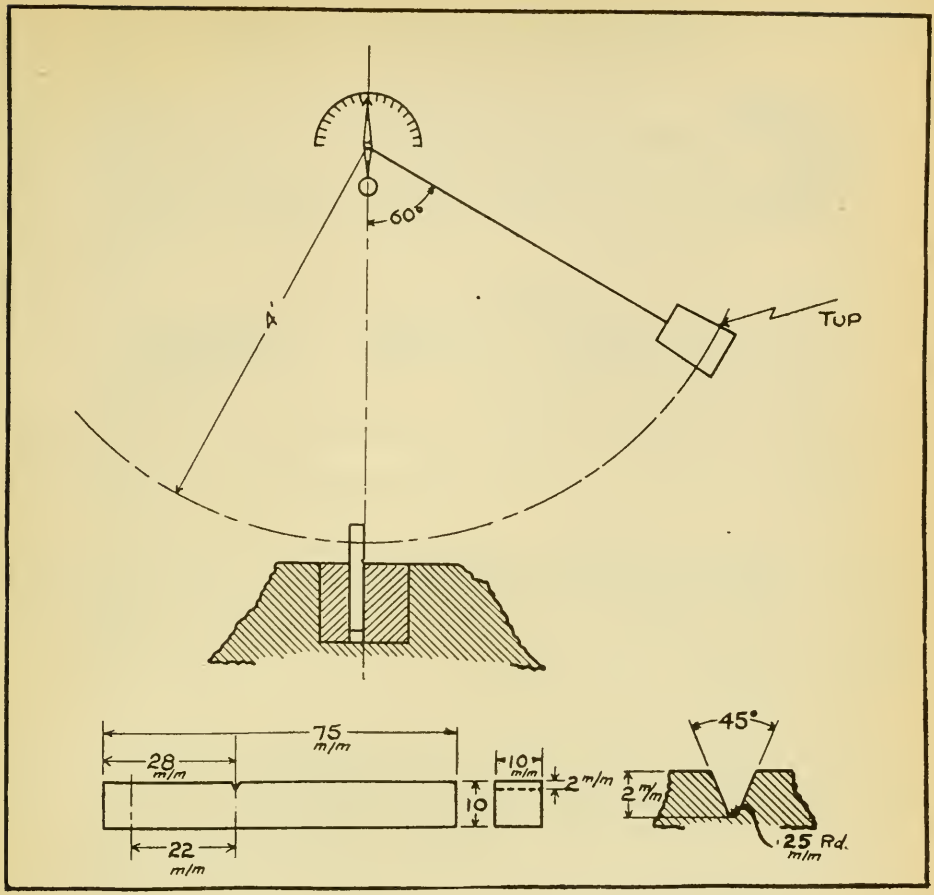


Fig. 3—Arrangement of Izod impact testing machine with sketch of test specimen shown below

by drilling a 1.3-millimeter hole so that the bottom of the hole is 5 millimeters from the edge. The notch is completed by running a 1-millimeter slot into the hole. This test piece is supported horizontally between 40-millimeter abutements and is struck by a swinging pendulum at the middle of its length on the side opposite the notch. The energy absorbed in making the fracture is determined from the residual energy after fracture. In Fig. 2 is shown a diagrammatic arrangement of the machine, and the test specimen employed. The weight of the tup is 32.5 kilograms. It will be noted that the machining of a notch of this nature requires at least two operations to complete it and is probably difficult to reproduce accurately on hard materials. This difficulty of obtaining notch uniformity is, of course, more or less inherent in all impact tests, but is probably more pronounced in this case.

The Izod test requires a test specimen which is 75 millimeters long with a cross section of 10 by 10 millimeters. It has a transverse 45-degree angle, V-shaped notch 2 millimeters deep as shown in Fig. 3; the radius at the root of the notch being 0.25 millimeter. The piece is held vertically in a vise with the lower edge of the notch at the same level as the vise edge

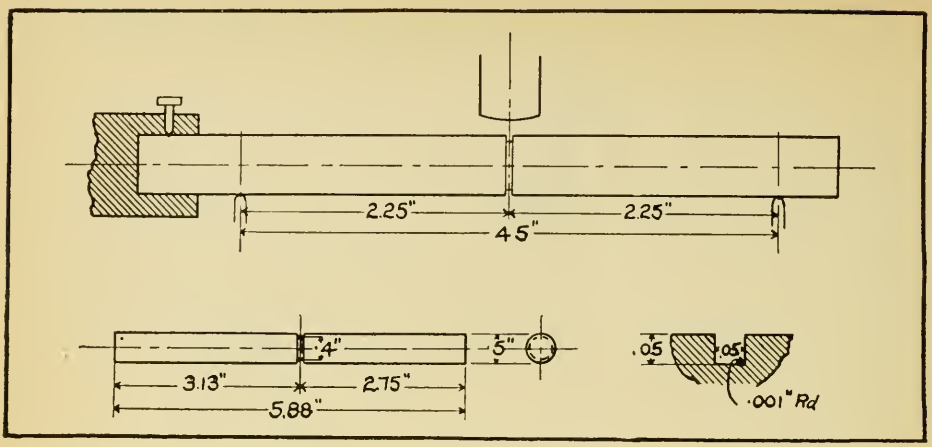


Fig. 4—Arrangement of Stanton repeated impact machine with sketch of test specimen shown below

and is broken by a swinging tup striking the test piece on the notched side but above it. As before, the residual energy deducted from the striking energy gives that energy which was required for fracturing the test piece. This energy is usually indicated on a scale by a pointer which is actuated by the swinging pendulum. The arrangement of the machine and a sketch of the test piece employed is shown in Fig. 3.

The Stanton test requires a test specimen about 6 inches long having a ½-inch diameter. It has a groove cut at the center, 0.05 inch deep and 0.05 inch wide. This test piece is held horizontally in supports 4½ inches apart and is rotated 180 degrees between successive blows which are struck over the groove by a falling tup. The weight of this hammer, or tup, is 4.7 pounds and the height of the fall is adjustable. The number of blows required to fracture the test specimen is recorded. Fig. 4 shows the diagramatic arrangement of this machine, and a sketch of the test piece employed.

It is proposed in the first place to discuss a few of the results obtained from the Izod machine and to confine the remarks to four grades of steel: namely, 1. Low carbon, 2. medium carbon, 3. nickel, and 4. nickel chrome.

In discussing test results, it is felt that curves are more convincing than tabulated figures. Therefore, the various impact characteristics, together with the other well known physical properties, for different grades of steel, are shown in Figs. 5 to 13 inclusive.

Fig. 5 represents a low carbon case-hardening steel plotted on a base of quenching temperature. The increase of impact value in the region of 760 degrees Cent. is quite characteristic of this class of material.

Figs. 6 and 7 show the properties of an oil hardening and an air hardening nickel chrome steel, respectively. These latter curves have been plotted on a base of Brinell hardness; the main features being the similar manner in which impact and reduction of area values and in a less manner, elongation values, respond to heat treatment variation. This response seems to indicate that the impact value has some relation to the structure of the ma-

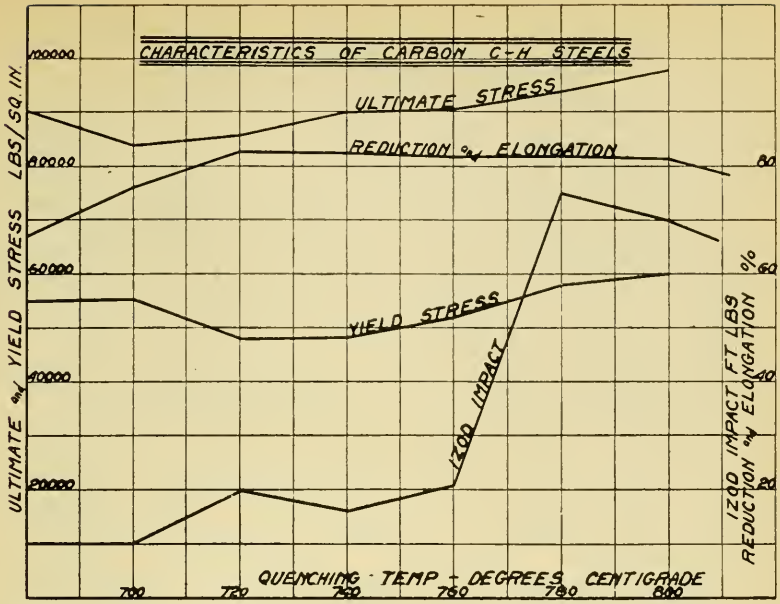


Fig. 5—Physical characteristics of carbon case hardening steels

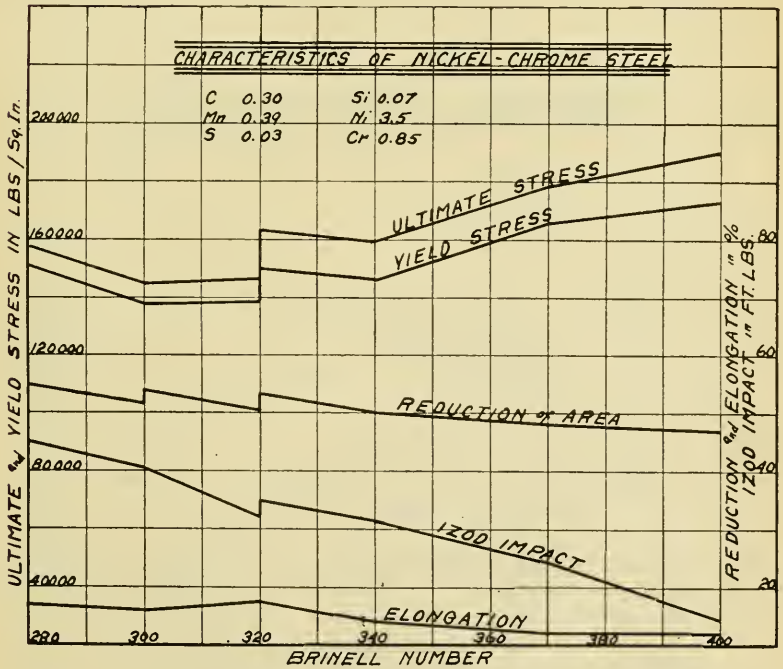


Fig. 6—Physical characteristics of nickel chrome steel

terial. This statement is further confirmed by the rapid increase of impact value as the quenching temperature is increased beyond a certain value, as shown in Fig. 5.

Figs. 8 to 13 represent a family of curves taken from the report of the Steel Research Commission, London, 1920, but confirmed by certain work of the author. In these curves, which are plotted on a base of drawing temperature, the manner in which the reduction of area varies with impact is again very striking. A further point for consideration is obtained from Figs. 9 and 10. The respective analyses of these two steels are approximately alike, provided the small percentage of nickel and chromium can be neglected in steel, Fig. 10. If this is true, then the difference of 30 degrees Cent. in drawing temperature has increased materially the impact values for allowing for observation errors; the other values remain practically constant. This, therefore, leads up to the conclusion that the impact test is a very sensitive one indeed and shows up by its results, when properly interpreted, small variations in thermal treatment.

Figs. 12 and 13 show up strikingly the effect of the addition of chromium to a nickel steel, for assuming that the upper limit of Brinell hardness from the point of view of machining is 320, a comparison of these steels is made in Table 1. A steel of 0.45 per cent carbon is also added for comparison.

It will be seen that although the Izod value in the nickel chrome steel is slightly lower, nevertheless, the benefit derived from the addition of chromium is apparent. Such a material would be suitable for high speed connecting rods where lightness is required. Referring to Fig. 13, it will be noted that the impact value commences to decrease at a drawing temperature of approximately 200 degrees Cent. and reaches a minimum value of 5-foot pounds at a temperature of 350 degrees Cent. It will be observed

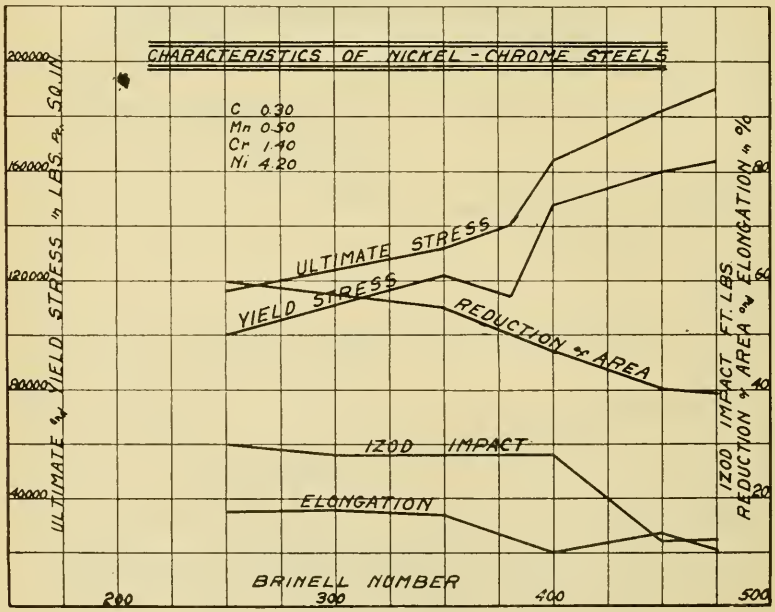


Fig. 7—Physical characteristics of nickel chrome steel

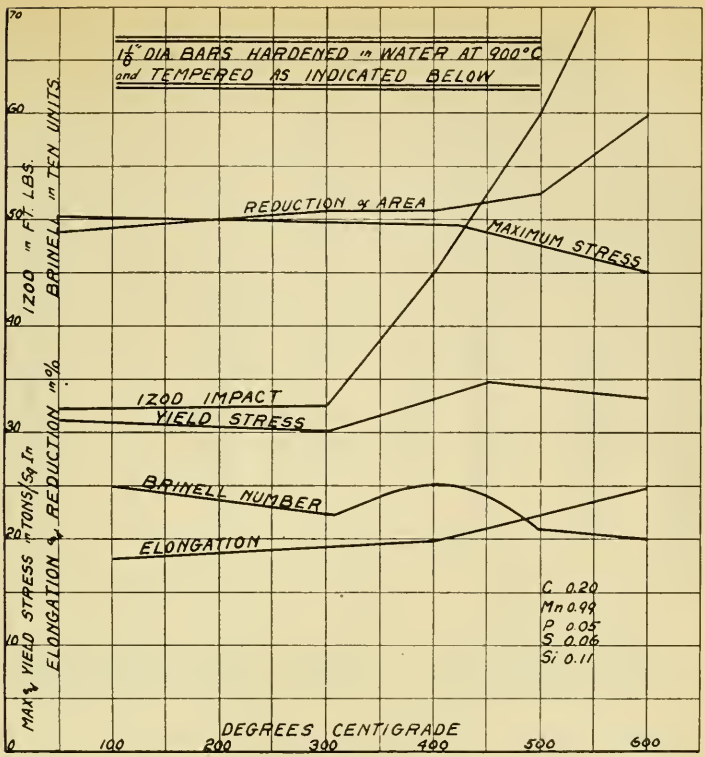


Fig. 8—Physical properties of bars 1⅛ inches in diameter hardened in water at 900 degrees Cent. and tempered as shown

Table I

Effect of Adding Chromium To a Nickel Steel

	Nickel Steel (See Fig. 12)	Nickel Chrome Steel (See Fig. 13)	Carbon Steel (See Fig. 11)
Brinell hardness	320	320	320
Maximum stress, pounds per square inch	153,000	170,000	145,000
Yield point, pounds per square inch	130,000	153,000	105,000
Elongation, per cent	16	18	13
Reduction of area, per cent	54	56	37
Izod impact, foot pounds	26	22	15

Table II

Physical Properties of Nickel Chrome Steel

Maximum stress pounds per square inch	Yield point pounds per square inch	Elongation per cent	Reduction of area per cent	Izod foot pounds	Brinell No.
Group A					
107,000	86,000	24	66	10	240
Group B					
110,000	85,000	25	64	80	240

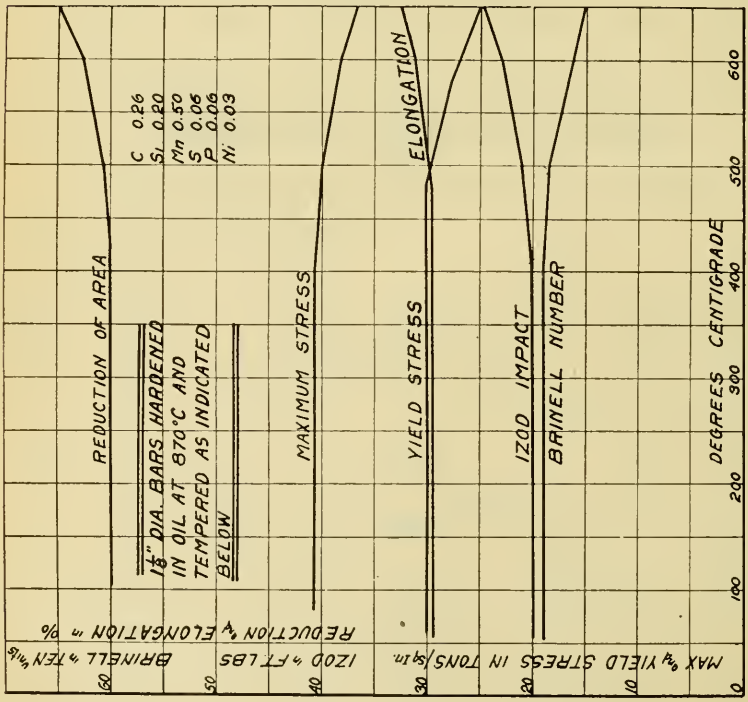


Fig. 9—Physical properties of 1⅛-inch diameter bars hardened in oil at 870 degrees Cent. and tempered as shown

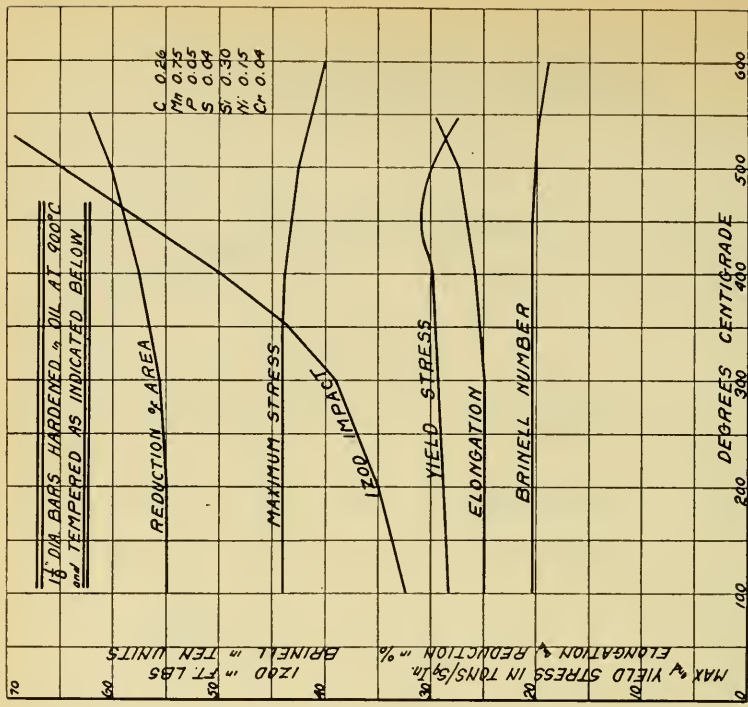


Fig. 10—Physical properties of 1⅛-inch diameter bars hardened in oil at 900 degrees Cent. and tempered as shown

also that the other physical properties show a steady change over this temperature range. This drop in impact value is known as temper brittleness and is a characteristic, more or less, of nickel chrome steels when slowly cooled through this range of temperature. It can be eliminated by rapidly cooling through this range by quenching from the drawing temperature. Therefore, once more is it apparent that the impact test has an intrinsic value, and in this case shows up undesirable characteristics which are not revealed by the tensile test. The following numerical values are given on this important phase of this subject. A steel of the analysis carbon 0.26, nickel 3.5, chromium 0.84, sulphur 0.02 and phosphorus 0.026 per cent in bar form 2 inches in diameter was oil hardened at 850 degrees Cent. and two lots *A* and *B* tempered at 650 degrees Cent.; the one lot *A* cooled in the furnace; the other lot *B* cooled by quenching from the tempering temperature. Twelve test pieces in *A* and in *B* give the average results shown in Table II.

While it is stated that a notch brittle, nickel chrome steel shows a crystalline impact fracture and is an undesirable material, the converse, of course,

Table III
Chemical Composition of One Series of Steels Tested

Steel No.	Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent	Chromium per cent
1.....	0.38	0.45	0.011	0.036	....	....
2.....	0.15	0.42	0.013	0.035	....	....
3.....	0.30	0.58	0.012	0.019	1.52	0.46

does not necessarily hold, that is, a crystalline fracture may not by itself demonstrate an undesirable material. The nature of these fractures must be judged in the light of their relation to the composition and the mechanical properties of the material. A crystalline fracture in medium carbon material as rolled may not be bad because this is normal for that material, but such a fracture for nickel chrome is abnormal and, consequently, is to be avoided.

There is still another feature of the impact test which must be considered, that is, the value of this test as indicative of the structure from examination of the fractured specimens. The tensile test is valuable in view of its being the repositore of a great deal of knowledge gained from its extended use. In a similar manner, an actual examination of fractured impacts will also contribute to making these tests valuable when these have been adopted more widely than at present. For example, and one which is by no means an isolated one, a material in the notch brittle condition always shows a crystalline impact fracture, while the corresponding tensile fracture is fibrous. It can be concluded, therefore, that such a material is unsuitable for structural purposes. This section deals with a series of tests which were carried out at East Pittsburgh to demonstrate these truths.

Three pieces of material 5 inches in diameter and 15 inches long of the analysis given in Table III were given the treatments as specified in Table IV, a series of test pieces being machined therefrom after each heat treatment operation. The test results which were obtained are shown in Table V, the numbers in the first column indicating the steel number and series, respectively, as shown in Table IV.

The bend test pieces were ground all over to ⅝-inch in diameter and bent over supports 4 inches apart to a radius of 0.5 inch. With the ex-

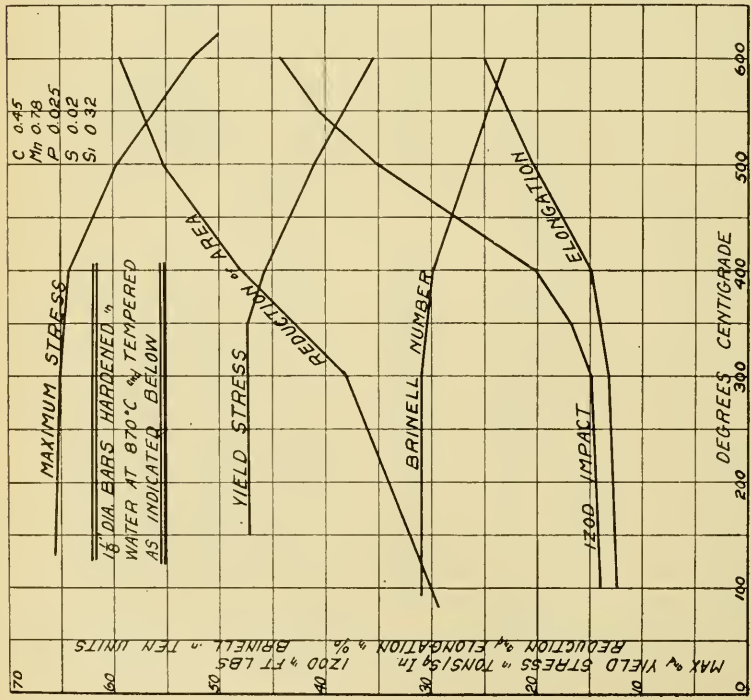


Fig. 11—Physical properties of 1⅛-inch diameter bars hardened in water at 870 degrees Cent. and tempered as shown

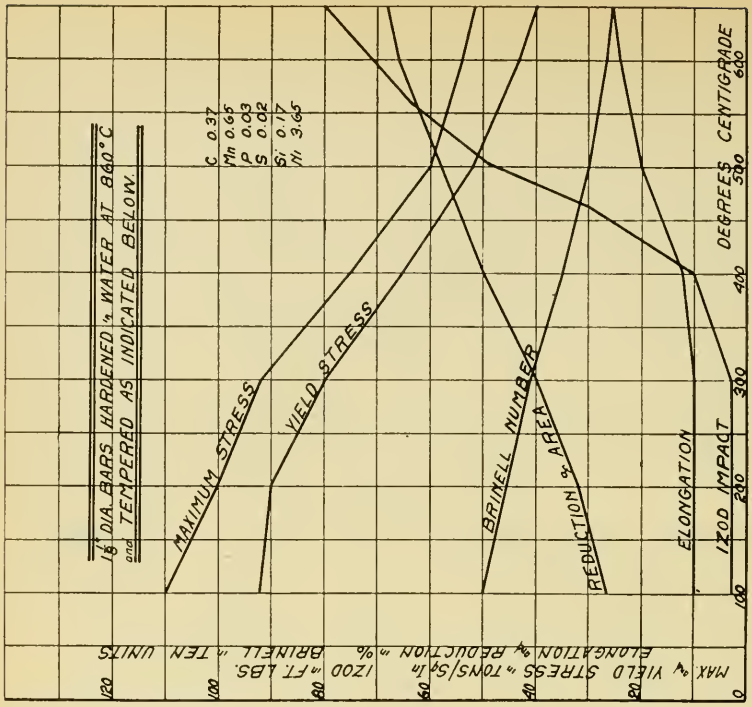


Fig. 12—Physical properties of 1⅛-inch diameter bars hardened in water at 860 degrees Cent. and tempered as shown

Table IV
Heat Treatments Given Steels Tested

Steel No. 1, Series No. 1

The material was drawn from stock as rolled and one quadrant cut out. Three tensiles, 3 impacts and 3 bend test pieces were machined for test.

Steel No. 1, Series No. 2

The material was normalized by putting it in the furnace at 450 degrees Cent., bringing it up to 875 degrees Cent. and holding it at that temperature for 2½ hours and then cooling it in the air. The test pieces were then machined from a second quadrant.

Steel No. 2, Series No. 1

The material was drawn from stock as rolled and one quadrant cut out. The test pieces were machined as before.

Steel No. 2, Series No. 2

The material was normalized as previously described and test pieces were machined as before from a second quadrant.

Steel No. 3, Series No. 1

The material was forged down from billets to 5 inches in diameter and test pieces were machined from one quadrant.

Steel No. 3, Series No. 2

The material was normalized in a similar manner and test pieces were machined from a second quadrant.

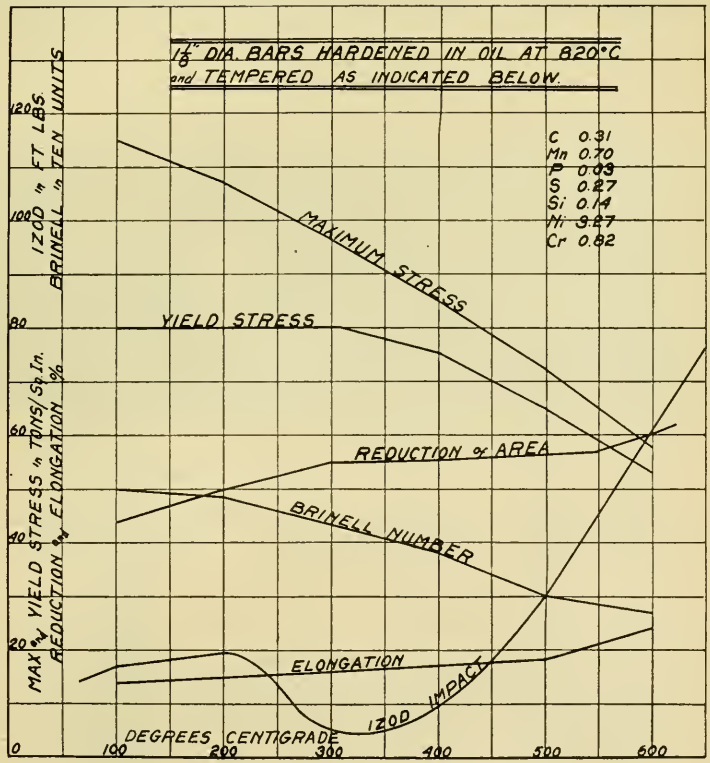


Fig. 13—Physical properties of 1⅛-inch diameter hardened in water at 820 degrees Cent. and tempered as shown

ception of the material No. 1 in the rolled condition, the bend tests went to 180 degrees without a sign of fracture. The impact tests, however, showed a somewhat different selection, indicating that this test is very sensitive. The macrographs of these tests are shown in Figs. 14 to 19 inclusive, these bring out the crystalline and fibrous natures of a given material and illustrate the assertion that examination of such, is a fund of knowledge.

Contrasted with these, macrographs of a medium carbon steel in an oil treated and tempered condition and also a steel casting unannealed are shown in Figs. 22, 21 and 20. The chemical composition of these steels was as follows:

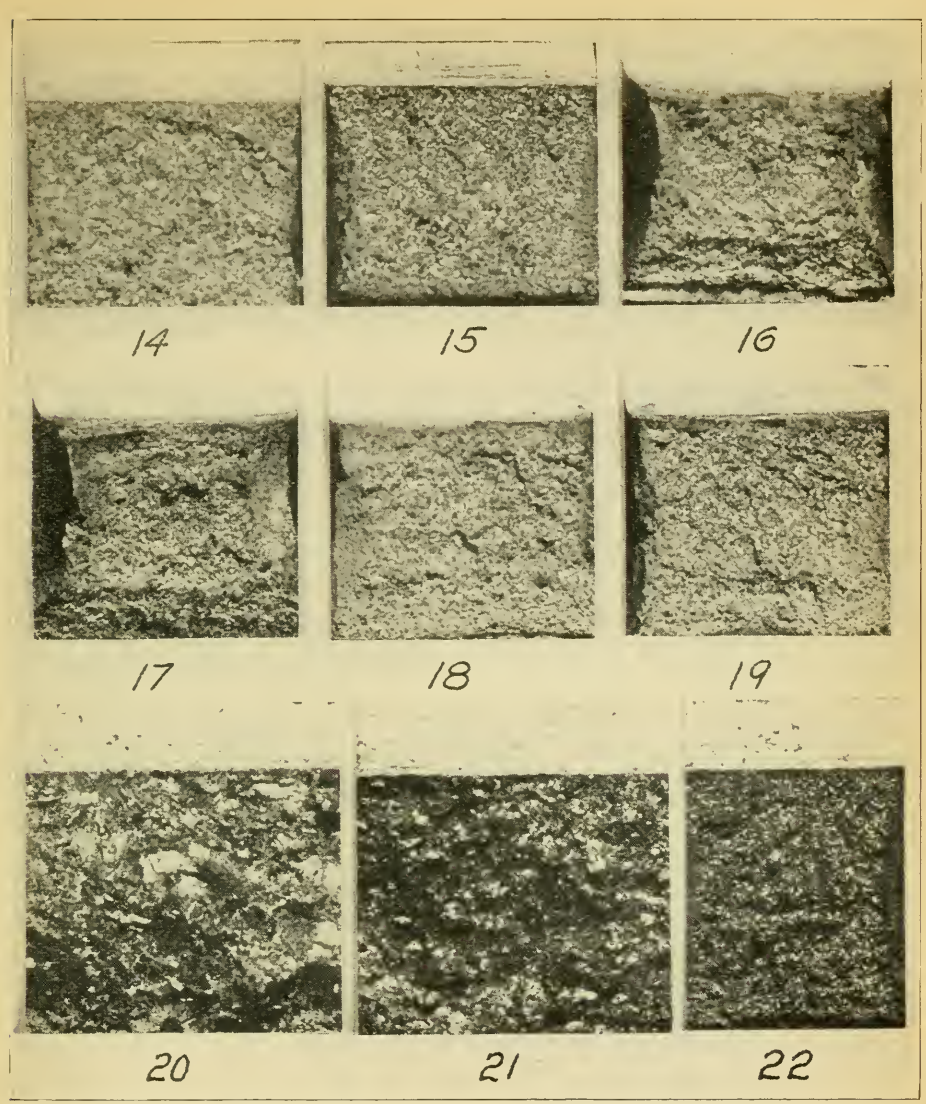
	Carbon per cent	Manganese per cent	Phos. per cent	Sulphur per cent	Silicon per cent	Oil quenched at degrees Fahr.	Tempered at degrees Fahr.
						Annealed at	
Fig. 20.....	0.13	0.74	0.059	0.119	0.13	As cast	....
Fig. 21.....	0.44	0.73	0.06	0.03	0.23	1500	....
Fig. 22.....	0.44	0.73	0.06	0.03	0.23	1500	1150

Caution always must be exercised in drawing conclusions from experimental data. Even with our present knowledge of material testing it is a difficult problem indeed to base a foundation on the results of certain tests. Due to this difficulty there is always the danger of building up a totally erroneous structure. Owing to the importance of this statement from a metallurgical standpoint, the author offers no apology for returning

Table V

Test Results Obtained With The Steels

Steel No. and series No.	Elastic limit —pounds	Yield point per square	Max. stress inch—	Elongation per cent	Reduction of area per cent	Brinell No.	Izod foot pounds	Izod macrograph Fig. No.	Bend test	Remarks
	23,375	28,000	72,400	28.7	38.8	134	7	14	Broke	
1/1	22,000	35,500	71,500	28.7	37.5	136	8	..	Broke	
	22,000	35,400	72,825	28.7	35.7	131	7	..	Broke	
	34,500	36,350	76,750	29.15	45.4	143	10	15	Bent to 180 degrees	
1/2	34,250	37,225	77,625	28.1	43.7	143	12	..	Bent to 180 degrees	
	34,750	36,770	77,575	28.7	46	149	12	..	Bent to 180 degrees	
	25,250	28,670	50,500	42	66.3	101	63	16	Bent to 180 degrees	Impact
2/1	25,750	27,400	50,600	42.5	67	104	61	..	Bent to 180 degrees	bent over but not broken off
	25,750	27,525	50,525	42	66.6	90	61	..	Bent to 180 degrees	
	27,500	28,625	47,670	44.3	73.3	90	40	17	Bent to 180 degrees	Impact
2/2	21,750	26,500	47,850	42.85	72.5	96	62	..	Bent to 180 degrees	bent over but not broken off
	22,750	27,500	47,900	44.9	73.1	101	69	..	Bent to 180 degrees	
	49,250	52,200	93,125	32.2	57.6	181	39	18	Bent to 180 degrees	
3/1	45,000	57,000	93,700	25.2	57.6	179	41	..	Bent to 180 degrees	
	43,750	53,250	92,900	24.15	57.3	179	37	..	Bent to 180 degrees	
	49,500	60,850	99,750	24.1	54.7	192	33	19	Bent to 180 degrees	
3/2	50,500	59,375	99,225	23.6	54.7	192	35	..	Bent to 180 degrees	
	48,750	60,300	98,550	23.0	56	192	32	..	Bent to 180 degrees	



Figs. 14-19—Macrographs of Izod impact fractures showing the crystalline and fibrous structures of the material X4. Fig. 20—Macrograph of medium carbon steel in an oil quenched and tempered condition. X4. Fig. 21—Macrograph of medium carbon steel in an annealed condition. X4. Fig. 22—Macrograph of an unannealed steel casting

again to this subject. For instance the Brinell test has often been put forward as a test in itself, while, as is known, it was never intended for such a use. It has a value only as it is related to some fundamental test such as the tensile test. It seems that this cannot be emphasized too strongly. There is some definite relation between the tensile strength and the Brinell hardness for a given material. Furthermore, attempts have been made in the past to correlate impact values and fatigue limits yet this seems erroneous since the conditions of fracture have nothing in common. The fatigue

fracture is determined by a series of slips in the material itself while the impact fracture is propagated by a notch definitely located in the specimen. The fact, therefore, remains that a material which gives a low impact figure may not necessarily show a low fatigue limit, but it is still revelant to state that the former material is in a notch brittle condition.

Therefore, although it is difficult and dangerous to make definite statements in favor of any particular test the following conclusions seem to be warranted:

1. The impact test of the type here described is one of the most sensitive mechanical tests so far introduced to determine the design of heat treatment given to a material.

2. This impact test shows up characteristics in certain materials which the tensile tests do not indicate.

3. The impact test corresponds along with other physical properties such as reduction of area to the variation in heat treatment and is therefore valuable for confirmatory purposes.

4. The impact test offers valuable evidence, by observation of the fracture, relative to the thermal treatment which the material has received.

Any test which brings out something new or confirms some value already known is valuable. Provided that this impact figure is not purchased at too high a price with respect to the ultimate strength or elastic limit these tests have a very great value indeed.

With regard to the repeated impact such as the Stanton the case is somewhat different. This test is in the nature of a fatigue test and may be closely related to the fatigue limits as determined by standard machines. This is a contention, however, which has yet to be proved.

The various points raised herein seem to be of sufficient importance to those interested in the heat treatment of steels to present them at this time. If enough interest is aroused to provide a satisfacory discussion of his subject the author will feel that his efforts have been well directed. Acknowledgment is extended to the Westinghouse Electric & Mfg. Co., for permission to publish these results and to W. J. Merten and C. H. Marshall for assistance in carrying out the tests described.

IMPORTANCE OF THE PROPER HEATING AND COOLING OF STEEL

By John A. Succop

ONE of the most important sciences in the mechanical field today, and one which necessitates the most careful and skilled application of its principles, if correct results are to be obtained, is the heat treatment of steel. There are certain fundamental facts and considerations which are worthy of attention. Of these facts, one of the most important is uniform results, which minimizes the possibility of low standard work. Uniform results are obtained through proper heating and cooling, and proper loading of the furnace charge. Less trouble is experienced with small masses, for they do not present the same difficulties that are encountered with large furnace loads. It is well known that the molecular changes which occur in steel are not fixed and unchangeable, but depend on both the temperature at which they take place and on the duration of time of changing, upon the rate of cooling and the initial temperature to which the steel has been heated.

It is generally assumed that the proper heat treatment of steel requires nothing more than a uniformly heated product; that a uniform product requires nothing more than a uniformly heated furnace; and that a uniform pyrometer record assures a uniformly heated furnace; consequently, a uniformly heated product within that furnace. When the pyrometer rod is used in a heat treating furnace, it should be so placed that by looking in the furnace door, a direct comparison can be made by the eye as to the temperature of the charge with the temperature at the end of the rod. The pyrometer rod should never be hidden from the eyes of the operator unless the couple be buried in the center of the material and protected from the flames.

From the study of the metallurgical results of the finished products, heat treated in an indicated, uniformly heated furnace, we find that a variation frequently is found. There is a greater problem to heat treating than the maintenance of a uniform temperature in the heating furnace. These variations are not confined only to furnaces of different types; for the variation is found in the same furnace, the pyrometer readings being the same in each case. Such variations are brought about by the position of the load in the furnace and by a difference in the heating of the load.

The best test of the uniformity of a heat treated piece of steel is the manner in which the load cools; for it is the uniformity of the steel as it passes through the critical range and takes its final and permanent set, that gives to steel the results of the heat treatment. To heat uniformly, it is necessary that each piece be subjected to the heat in the same manner, at the same temperature, and for the same length of time in proportion to the size of the section.

If a large amount of material is placed on one end of the furnace charge, it is likely that the outside pieces will be heated to and cooled from a higher temperature than the pieces at the center of the mass. Likewise with cooling, if a large mass is plunged into a quenching tank, there is a tend-

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A paper to be presented at the Pittsburgh Sectional Meeting, May 25-27. The author, John A. Succop, is connected with the Heppenstall Forge & Knife Co., Pittsburgh.

ency for the temperature of the bath to become irregularly heated, and also for the outside of the mass to cool at a different temperature and in a different temperature and in a different period of time than the center.

With large masses, it is unreasonable to suppose that each portion of the section receives the same amount of heat that the other portions received, and that it is subjected to the same heat treatment. Unless all pieces are heated and cooled exactly alike, the pyrometer indications of uniform temperature serve merely as evidence, but cannot be accepted as proof of a uniformly heated furnace, or a uniformly heat treated furnace charge, or a uniformly heat treated product, as a final result. There should be better appreciation and understanding of the difference between a pyrometer record, which indicates a uniform temperature and of the conditions which bring about the uniformity desired in the furnace.

The following is a quotation from Dr. Howe in his book, *Iron, Steel and Other Alloys,* page 241: "You cannot make a bad beefsteak good by the cooking; you can cook it better or worse, and it will be a worse or less bad beefsteak, but always bad. On the other hand, you can easily spoil a good beefsteak by bad cooking. Now, just as cooking is to food, so is heat treatment to steel. Indeed, a pedantic cook might reasonably call cooking, heat treatment." This simile of Dr. Howe's is right to the point; for the application of heat to industrial material is but a cooking operation, like the cooking of food or the baking of bread; each must be thoroughly done—that is, it must be heated uniformly to the center. To cook or heat to the center with the temperature being equal from the surface to the center requires a slow fire and time in proportion to the amount of material to be heated. Overloading, as well as improper loading, will prevent the proper circulation of heat, and it is likely that a part of the charge will rise to the desired temperature in a nonuniform condition, and will cool with even less uniformity than it heated. The indicator on the outside of the oven does not tell the story of the food being well done. This is accomplished by observation of the material.

Even with all our modern present day practice and equipment we must take into consideration the importance of the human element. The heat treater, although the weakest link in the chain of perfection of the product, is the one that puts the metallurgical finish on the material at a great expense to others, and it is his skill and judgment that either perfects or spoils the material. Have we not all heard of the manufacturer who thinks he is protected from all the evils of heat treatment because he has the best pyrometer system that money could buy, with automatic recorders in the office, so that at all times, he knows the condition of the furnace and what each heater is doing? Besides this, he has a man whose sole duty it is to watch these instruments and the temperature recorded on the pyrometer, and to indicate to the operator by a red, green, or blue light just when his temperature is low, high or just right. He is sincere in his belief and he thinks he knows what good heat treating is, but his standard is low, due to the reasoning that a uniformly heated product requires only a uniformly heated furnace, which reasoning leads to the development of the pyrometer to indicate the uniformity of the product.

This is all right as far as it goes, but it does not go far enough, for it may be an indication of the temperature of that particular part of the furnace, but it surely is not proof that the product in the furnace is at that particular temperature, as indicated. The proof for this statement is the

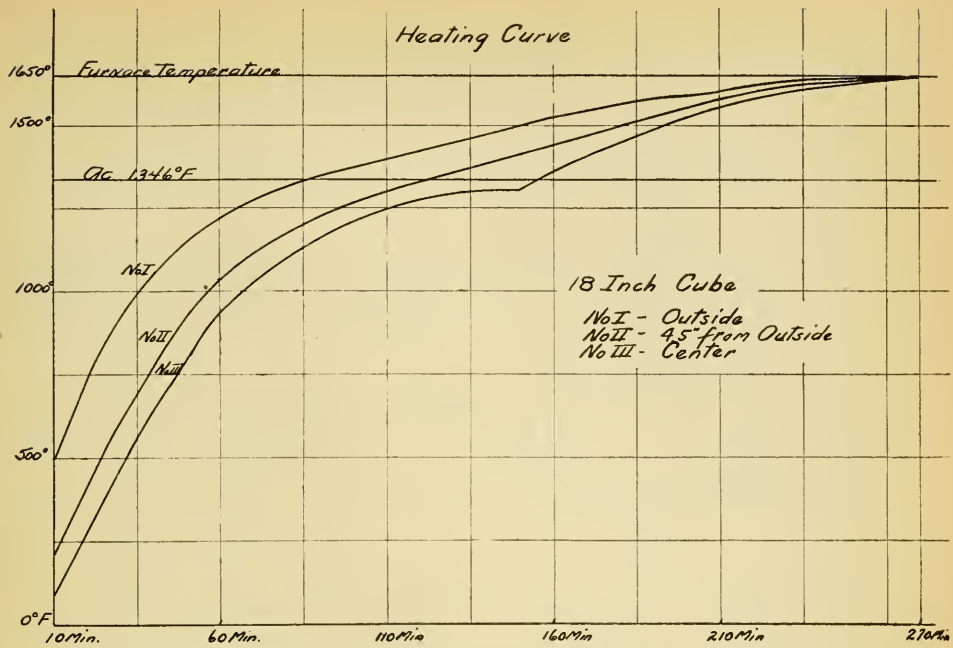

Fig. 1—Curves representing the heating of a steel block 18 inches square showing the rapidity with which the heat penetrates to the center of the mass

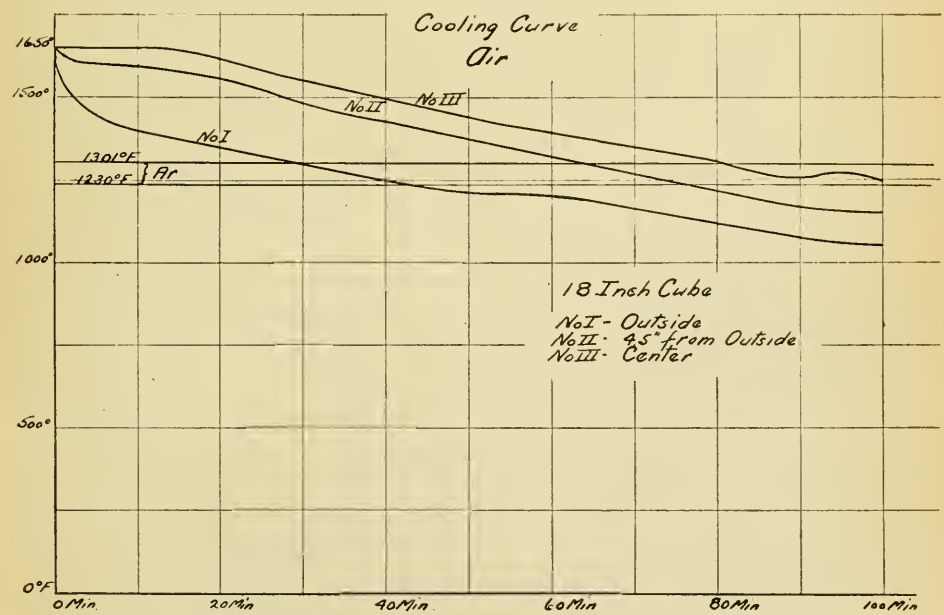

Fig. 2—Curves representing the cooling of a steel block in the furnace. The cooling takes place slowly

trouble we encounter with variations in the finished product, although the pyrometer chart gives no indications of a temperature variation. The uniform heating of a furnace and of the product within that furnace are two entirely distinct operations, and while the former must accompany the latter, yet the former does not prove the existence of the latter. The final conclusion of this analagous reasoning is that it is neither logical nor conclusive, and the actual results all hinge on the experience and knowledge of the man at the furnace.

There are a number of elements that directly affect heat treatment. They are not indicated by the use of pyrometers or other heat determining devices, whether mechanical or electrical, but are determined by the judgment and skill of the operator at the furnace, as the cook judges the quality of the food baked in the oven.

When the pyrometer indicates the desired temperature, what determines when the charge in the furnace is completely saturated?

What determines proper loading conditions as regards to mass heating and gas circulation?

What determines when the temperature of the bottom of the mass is equal to the temperature of the center, and when the top equals the sides?

What regulates the flow and combustions of the fuel into the furnace, causing an oxidizing, reducing, or neutral action?

What regulates the uniformity of each piece, compared with each other piece in the charge, that they might all be treated the same?

The four factors which govern the heating and cooling of all material, whether it be food or an ingot of steel, are temperature, time, surface and mass.

Temperature. This is the degree of heat required to produce the desired molecular structure and grain size.

Time. This is the period required to saturate the piece to the required temperature, and to permit the metallurgical reactions to take place.

Surface. This is the area of the section exposed to the heat, which influences the rate of absorption, the time of soaking, and the uniformity of the piece.

Mass. This is the amount of material to be heat treated, which influences the time of heating, and the time of saturation and uniformity, as well as the manner of supplying the heat.

Of these four, temperature and time are the important factors. Temperature is determined by the metallurgical effect that is desired, but time is governed by the surface and mass, and also by the type and composition of the material being treated. That is, the time necessary to soak a piece of low carbon steel might vary from the time necessary to soak a piece of alloy steel. Soaking means the completion of the metallurgical reactions that take place upon cooling and heating the steel. Often our time for allowing the sections to become saturated is not enough, and our results are not uniform. When loading, the largest surface should be exposed to the source of heat to insure the minimum time and maximum uniformity. The reverse would mean that it would be necessary to expose the outside surface of the mass to the heat for a greater length of time than the section at the bottom of the mass. Ideal cooling is just the same condition reversed.

A striking example of this is found in a large die block, where the corners heat and cool much more rapidly than the main body of the die. Every

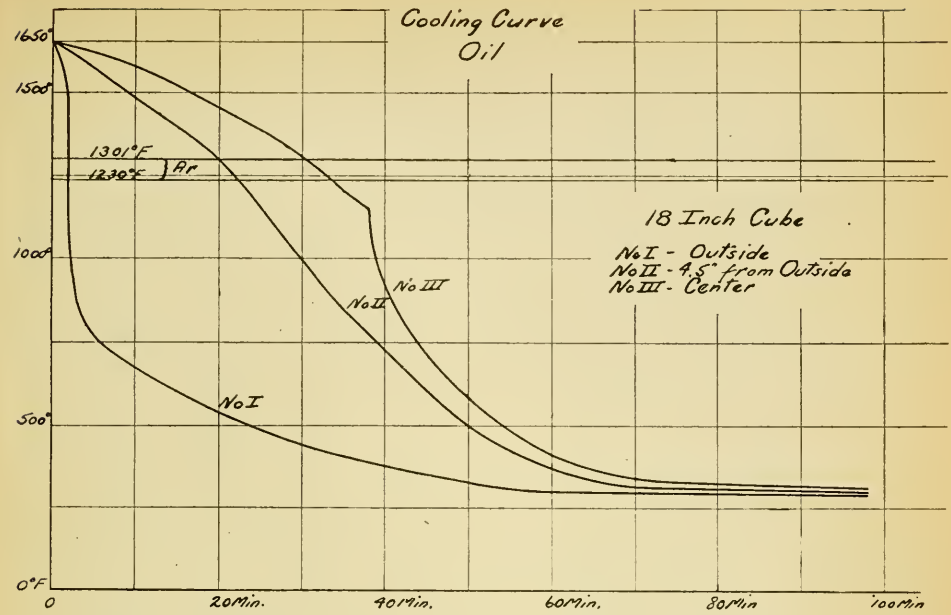

Fig. 3—Curves representing the cooling of a steel block in quenching oil, the rapidity of cooling being due to large volume of oil and its rapid circulation

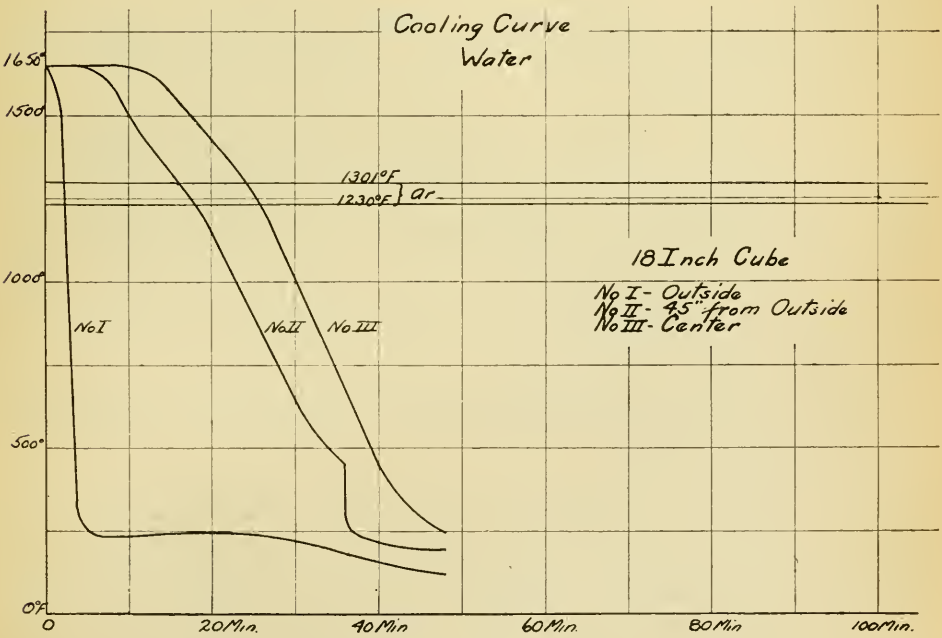

Fig. 4—Curve of a steel block heated to 1650 degrees Fahr. and cooled on knife edges by a high pressure water spray. Cooling is more rapid than in the water quench

possible effort should be made to prevent overheating the corners or exposing them to the extreme final temperature any longer than is absolutely necessary. This might be accomplished by thoroughly saturating the dies at a temperature slightly below the final temperature. The corners of a die, because of the greater surface, heat first and cool off first, and cause an unequal expansion and contraction in the steel.

The effect of mass on the heating and cooling of steel might be clearly shown by a study of the curves developed by Law. These curves were produced under as ideal a condition as possible, and they represent the changes that are found in a large mass of steel during the heating and cooling. The curves were developed by the following means: Eighteen-inch cubes were forged from a 25-inch ingot, only the soundest part of the ingot being used. The thermocouples were inserted into the cubes to be treated—one in the center; 4½ inches from the center, that is midway between the center and the outside; and one ¼-inch from the center of the surface.

Fig. 1 represents the heating of a block of steel 18 inches square, and shows the rapidity with which the heat penetrates to the center of the mass. The center and outside temperatures approach each other before going through the critical range, but at this point, the absorption of heat due to the Ac change causes a greater lag at the center than anywhere else, and the two temperatures fall away from each other for a period of time. However, after being in the furnace for about 4½ hours longer, the cube attains a uniform temperature throughout its mass, and practically coincides with the temperature of the furnace.

Fig. 2 represents the cooling of a block in the furnace. These curves require no explanation. The cooling takes place slowly, and as in the case of the heating curves, the evolution of the heat is most marked in the center of the mass.

Fig. 3 represents the cooling of a block in quenching oil. The rapidity with which the block cools in the oil bath is due to the large volume of oil and the rapid circulation.

The block shown in Fig. 4 was heated as before to 1650 degrees Fahr. and cooled on knife edges by a high pressure water spray. The block, as would be expected, cools off more rapidly than the oil quench. The curve also shows an evolution of heat in the center. Attention is called to the abrupt halt in the cooling at about 250 degrees Fahr. It is hardly likely that this halt is caused by the water getting into the thermocouple hole, because the temperature remains constant for so long a time, and at 50 degrees above the temperature of boiling water. Experiments repeated on various sizes of blocks show that the phenomenon occurs with remarkable regularity and is not affected by mass.

The existence of a low critical point has been verified by a large number of scientists, and if proved correct, will throw a new light on the phenomenon of hardening in steel.

Law sums up the essential features of the curves as follows: "The extreme slowness of air cooling, as compared with either water or oil cooling, is too obvious for comment. A comparison of the curves obtained by oil and water cooling, however, is of greater interest. The important difference between the two methods of cooling is to be found in the almost sudden slowing up of the cooling in oil shown in the lower ranges of temperature, as compared with the cooling in water. For example, the time required for the center of the cube to cool from 1650 to 1000 degrees Fahr., a tempera-

ture well below the critical range, is almost the same whether oil or water is used as the quenching medium. In cooling from 1000 to 600 degrees Fahr., however, the cube cooling in oil requires twice the time, and in cooling from 600 to 300 degrees Fahr., it requires nearly four times as long. The differences are even greater on the outside of the cube. The oil cooled surface takes six times as long as the water cooled surface to cool from 600 to 300 degrees Fahr. It may be observed with interest that both in oil and water cooling, there is a period during which the metal in the center of the cube is cooling down more rapidly than the metal midway between the center and the surface."

These factors hold good with a furnace loaded with both large and small pieces where, in order to cut the cost, the load is heated according to the perfection of the small pieces. Although the initial costs are increased, the best results are obtained by heating according to the largest section, which undoubtedly will pay in the end for the additional time necessary, but an ideal condition would be to heat treat as nearly as possible, loads made up of parts of uniform size.

The practice of heat treating without regard to the mass and surface and with an eye only on the record of the pyrometer, will always produce a nonuniformly heated product. The mass should be heat treated and not the pyrometer. The pyrometer does not indicate anything concerning the temperature of the mass, but only the temperature of the portion of the gases in the furnace or the material with which it comes in contact.

Proper consideration must be given to the human element involved. Those in charge should be educated and should in turn educate those within their charge, for upon them lies the future of subsequent operations.

From the foregoing discussion, the following conclusions might be drawn:

1. That a uniformly heated product requires more than a uniformly heated furnace.
2. That material cannot be heat treated satisfactorily when the record of the pyrometer is the only guide.
3. That the human element plays an important part in the proper heating and cooling of steel.
4. That great care must be exercised in the handling of steel to insure proper thermal expansion and contraction. This is secured only through proper loading, charging at a low temperature, and by slow firing.

THE ABRASIVE QUALITIES OF PLAIN CARBON AND ALLOY STEELS

By A. M. Cox

MODERN equipment is designed for high speed and heavy duty. The manufacturers have met this condition by using heat treated plain carbon and alloy steels in moving parts, such as gears, cams, etc. Application of various types and grades of steel has brought forward the fact that any one steel cannot be used indiscriminately but must be studied in relation to the service for which it is intended. This paper gives the results of a series of tests as an introductory study of the effect of heat treatment on the abrasive qualities of plain carbon and alloy steels; after having been sujected to various heat treatments.

The machine used for these tests is shown in Fig. 1. The type of rollers used are shown also. The arrangement of the rolls and the dimen-

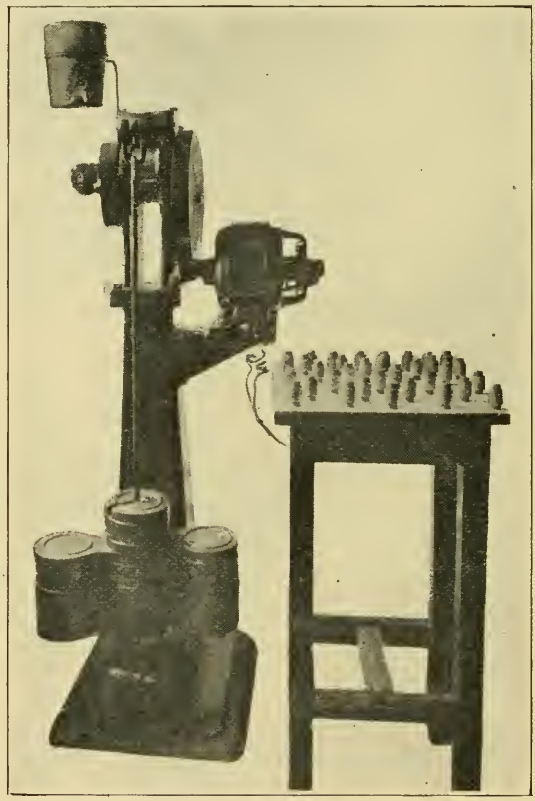

Fig. 1—Machine used for making abrasive tests on steel rollers

sions of the test roller are shown in Fig. 2. The pressure on the test roller is a dead load of 240 pounds. The machine is direct motor-driven

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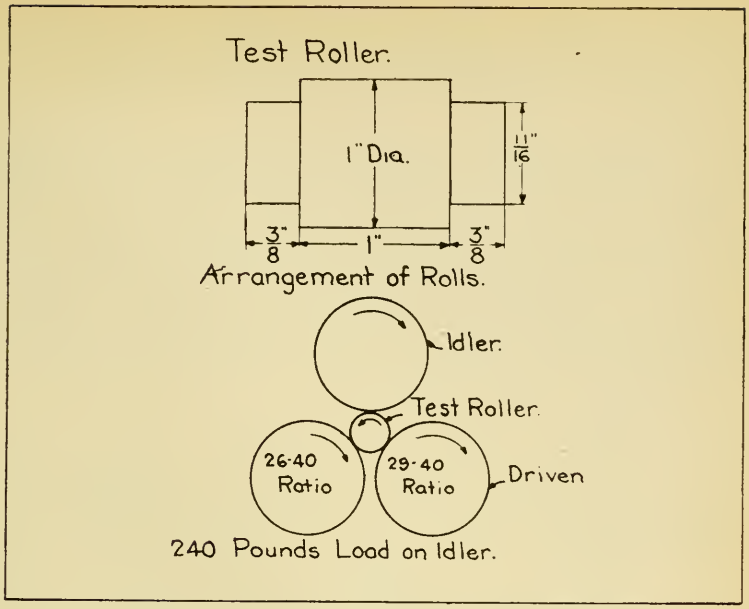

Fig. 2—Arrangement of rolls and dimensions of test roller. For each revolution of the counter, the front driven roll turns 100 revolutions while the test roller turns 300 revolutions or 750 revolutions per minute

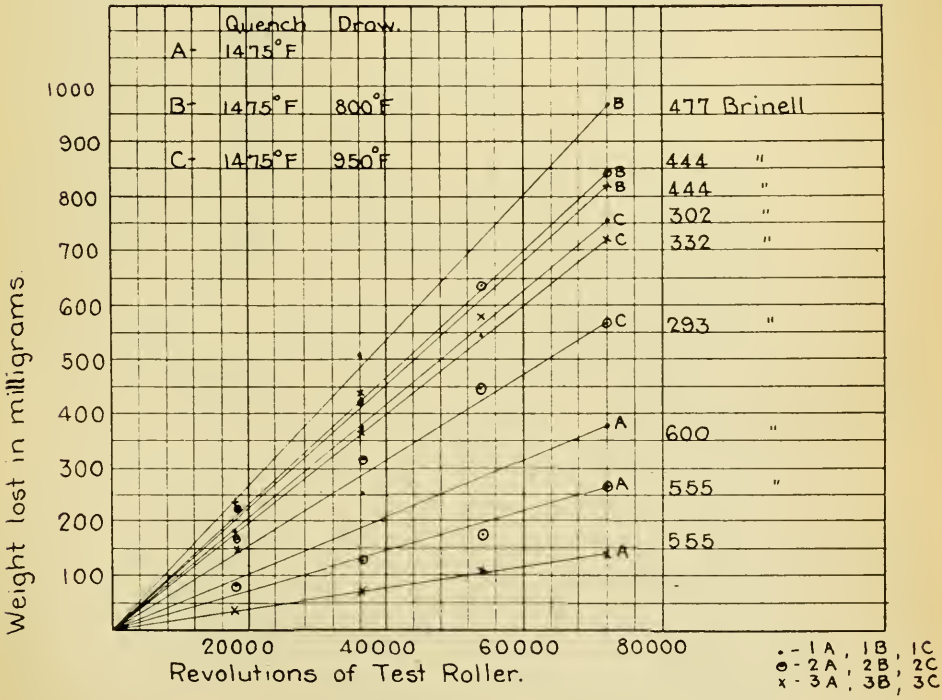

Fig. 3—Curve showing wear of plain carbon steel No. 1, brine quenched

having a motor speed of 1140 revolutions per minutes. The 20-tooth motor pinion drives a 106-tooth gear. At the other end of the shaft holding the 106-tooth gear is a 40-tooth pinion, which drives the lower rolls. The front roll is operated by a 29-tooth gear and the back roll is operated by a 26-tooth gear.

This arrangement gives the rolling and sliding action to which gear teeth are subjected. There is approximately 10 per cent sliding at all times whereas the ratio of sliding to rolling obtained in involute gear teeth varies. An involute tooth wears more rapidly below and above the pitch line since at these points the contact is both sliding and rolling. At the pitch line the contact is pure rolling. Since these extreme contact points should pass through the arc of contact in the same time as a point on the pitch line, if the surfaces are worn so as to shorten their arcs of contact, they will have to travel slower in order to cover their arc of contact in the same time that a point on the pitch line covers its arc of contact which is longer.

This causes vibration which varies in frequency with the speed. The above is stated here in order to show the difficulty in approximating the actual wear conditions of gear teeth in service by any type of wear or

Table I
Chemical Composition of Steels Tested

Per Cent	Carbon Steel No. 1	Carbon Steel No. 2	Chrome Nickel Steel No. 3	Chrome Nickel Steel No. 4
Carbon	0.520	0.226	0.550	0.240
Manganese	0.340	1.020	0.300	0.290
Phosphorus	0.016	0.077	0.030	0.032
Sulphur	0.039	0.063	0.042	0.039
Silicon	0.090	0.030	0.170	0.130
Nickel			1.840	1.490
Chromium			0.990	1.150

abrasion testing machine. The machine is equipped with a counter. One revolution of the counter occurs for every 100 revolutions of the first roller. The three large rolls are 3 inches in diameter and are made from Hadfield 14 per cent manganese steel.

Four kinds of steel were studied, two plain carbon steels of low and medium carbon content and two chrome nickel steels of low and medium carbon content. The chemical composition of these steels is shown in Table I. The specimens of carbon steel No. 1 were selected from a specially forged 6-inch bar. The specimens of carbon steel No. 2 and of alloy steels No. 3 and No. 4 were selected from a hot-rolled 2-inch bar.

Steel No. 1 was made into nine test rollers. These were heated uniformly to 1475 degrees Fahr. and quenched in brine solution. Three of the test rollers were left in this condition, having a Brinell hardness of approximately 555. These are designated in Fig. 3 as 1*A*, 2*A* and 3*A*. Three of the test rollers were given a draw back at 800 degrees Fahr. giving a Brinell hardness of approximately 444. These are designated in Fig. 3 as 1*B*, 2*B* and 3*B*. Three of the test rollers were given a draw back at 950 degrees Fahr. giving a Brinell hardness of approximately 302. These are designated in Fig. 3 as 1*C*, 2*C* and 3*C*.

Steel No. 2 was made into six test rollers. These were carbonized

at 1750 degrees Fahr. to give a 1/10-inch case. Three of the test rollers were heated uniformly to 1380 degrees Fahr. and quenched in brine solution, then given a draw back at 350 degrees Fahr. in oil. The scleroscope hardness averaged 89 to 91. This treatment is known as single quench case hardening.

Three of the test rollers were heated uniformly to 1475 degrees Fahr. and quenched in oil. They are reheated to 1380 dgrees Fahr. and quenched in brine solution and given a draw back at 350 degrees Fahr. in oil. The scleroscope hardness averaged 88 to 89. This treatment is known as double quench case hardening S. A. E. treatment G. Steel No. 2 is designated in Fig. 5 as 1*S*, 2*S* and 3*S* and 1*D*, 2*D* and 3*D*. *S* represents the single quench and *D* the double quench treatments.

Steel No. 3 was made into nine test rollers. These were heated uniformly to 1425 degrees Fahr. and quenched in oil. Three of the test

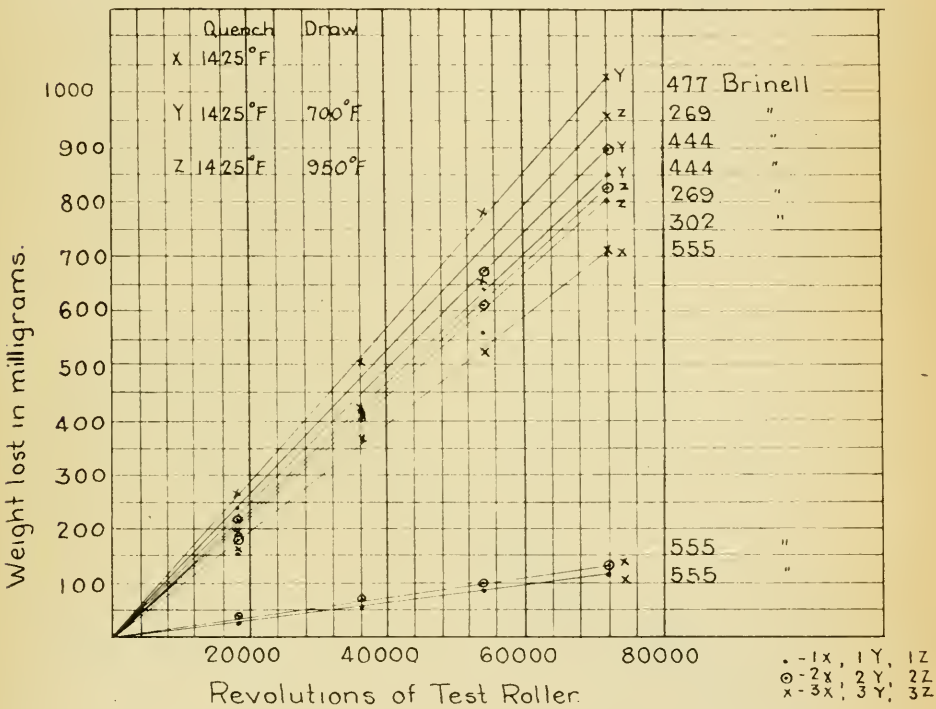

Fig. 4—Curve showing wear of chrome nickel steel No. 3, oil quenched

rollers were left in this condition, having a Brinell hardness of approximately 555. These are designated in Fig. 4 as 1*X*, 2*X* and 3*X*. Three test rollers were given a draw back at 700 degrees Fahr. giving a Brinell hardness of approximately 444. These are designated in curve Fig. 4 as 1*Y*, 2*Y* and 3*Y*. Three test rollers were given a draw back at 950 degrees Fahr. giving a Brinell hardness of approximately 302. These are designated in Fig. 4 as 1*Z*, 2*Z* and 3*Z*. The treatment given is similar to S. A. E. treatment F.

Table II
Average Wear in Milligrams Per 18,000 Revolutions

Material	Weight	Hardness Brinell	Weight	Hardness Brinell	Weight	Hardness Brinell	Markings
Carbon	94.9	600	* 55.0	555	36.5	555	A -1, 2 and 3
Steel	243.0	477	*212.0	444	207.0	444	B -1, 2 and 3
No. 1	189.0	302	*142.0	293	132.4	332	C -1, 2 and 3
Chrome Nickel	29.4	555	* 32.4	555	179.0	555	X -1, 2 and 3
Steel	213.8	444	*225.1	444	258.9	477	Y -1, 2 and 3
No. 3	203.0	302	*210.5	269	239.7	269	Z -1, 2 and 3
		Scleroscope		Scleroscope		Scleroscope	
Carbon	S. 25.9	90	* 26.3	91	23.1	91	S -1, 2 and 3
Steel No. 2	D. 26.1	89	29.3	88	* 20.6	89	D -1, 2 and 3
Chrome nickel	S. 19.0	89	26.4	92	* 28.4	89	S -1, 2 and 3
Steel No. 4	* D. 30.1	89	18.1	88	35.3	89	D -1, 2 and 3

Test roller weighed 136 grams approximately. Total revolutions of test roller—72,000. Total distance covered—3.6 miles.

S—Single Treated, Case Hardened. D—Double Treated, Case Hardened. *Taken for Micro-Photo.

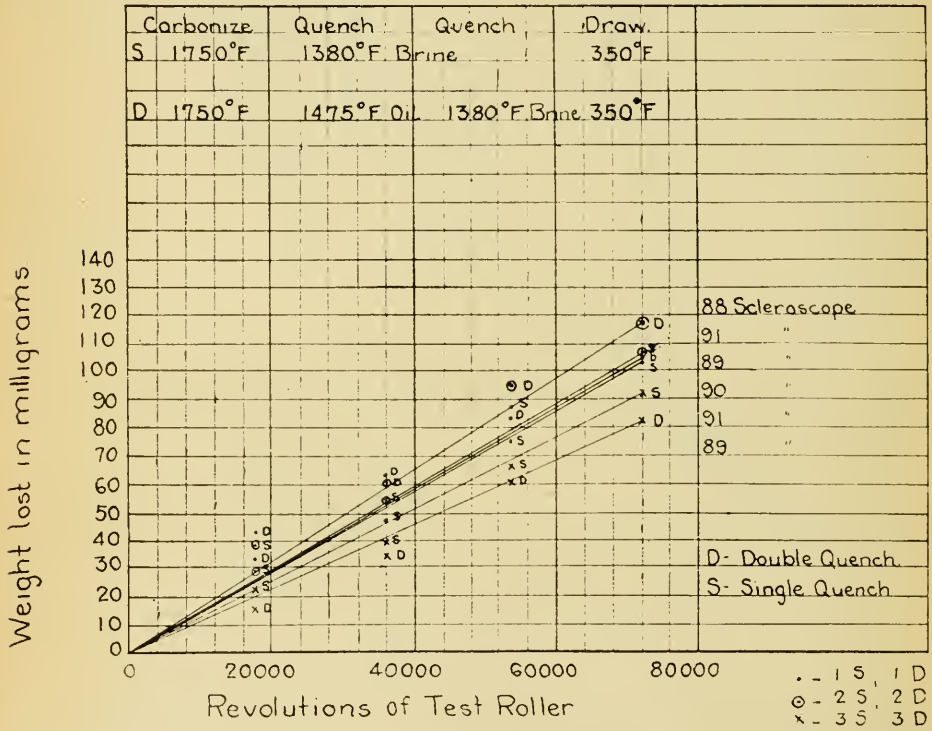

Fig. 5—Curve showing wear of plain carbon steel No. 2, case hardened

Steel No. 4 was made into six test rollers. These were carbonized at 1750 degrees Fahr. to give a 1/10-inch case. Three of the test rollers were heated uniformly to 1400 degrees Fahr. and quenched in brine solution and then given an oil draw at 350 degrees Fahr. The scleroscope hardness averaged 89 to 92. Three of the test rollers were heated uni-

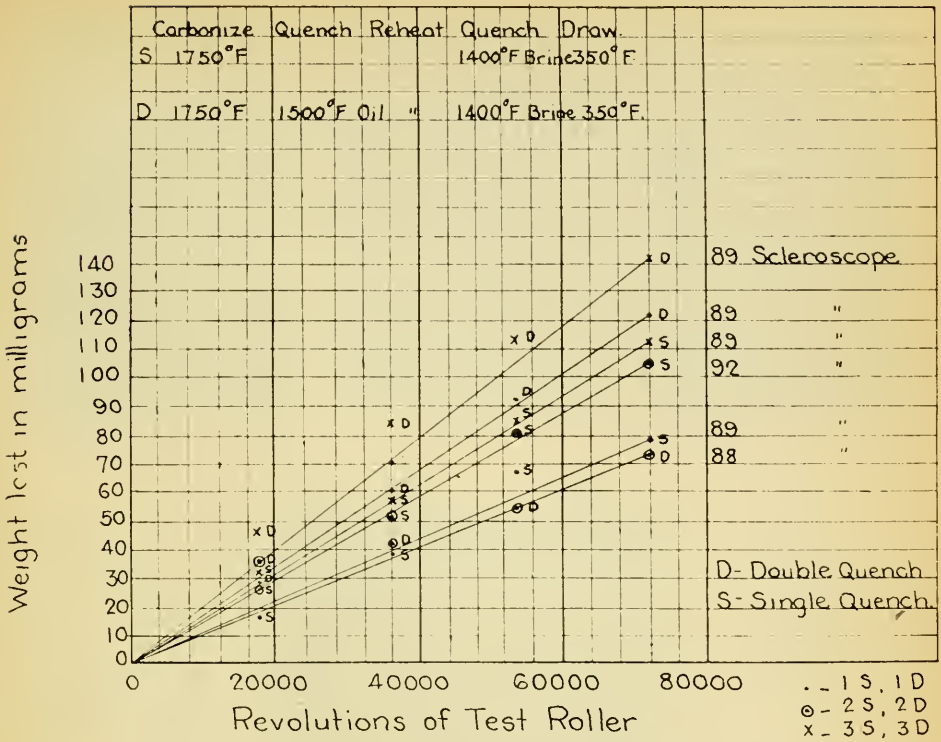

Fig. 6—Curve showing wear of chrome nickel steel No. 4, case hardened

formly to 1500 degrees Fahr. and quenched in oil. They were reheated to 1400 degrees Fahr. and quenched in brine solution, then given an oil draw at 350 degrees Fahr. which is S. A. E. Treatment G. The test rollers were turned 0.010-inch oversize on the outside diameter to allow for grinding after heat treatment. This eliminated any slight decarbonization that may have occurred at the surface of the test rollers.

One inch bars were made from steel No. 1 and steel No. 3. These were heat treated as shown in Figs. 7 and 10 and are designated *A, B, C,* and *X, Y, Z* respectively. Tension tests were then made from these bars, to compare the physical properties with the abrasive properties.

The small test rollers were weighed on a laboratory balance accurate to 0.1 milligram. Each run between weighings consisted of 60 revolutions of the counter or 18,000 revolutions of the test roller. The time of each run was 24.5 minutes. The results were plotted using the revolutions of the test roller as abscissas and weight lost in milligrams as ordinate.

A study of Fig. 3 shows that when the Brinell hardness of steel No. 1 falls below the maximum that can be obtained for that particular steel, the wear loss does not follow the Brinell hardness. Also in Fig. 7 the average wear obtained from the three ranges of hardness is plotted with the physical properties over the same hardness range. Here we find the wear increasing at 470 Brinell and then decreasing at 302 Brinell. The wear loss of each test roller was in a straight line ratio. The structures of the three specimens are shown in Fig. 8.

The curve in Fig. 4 shows the plotted results of the wear loss of steel

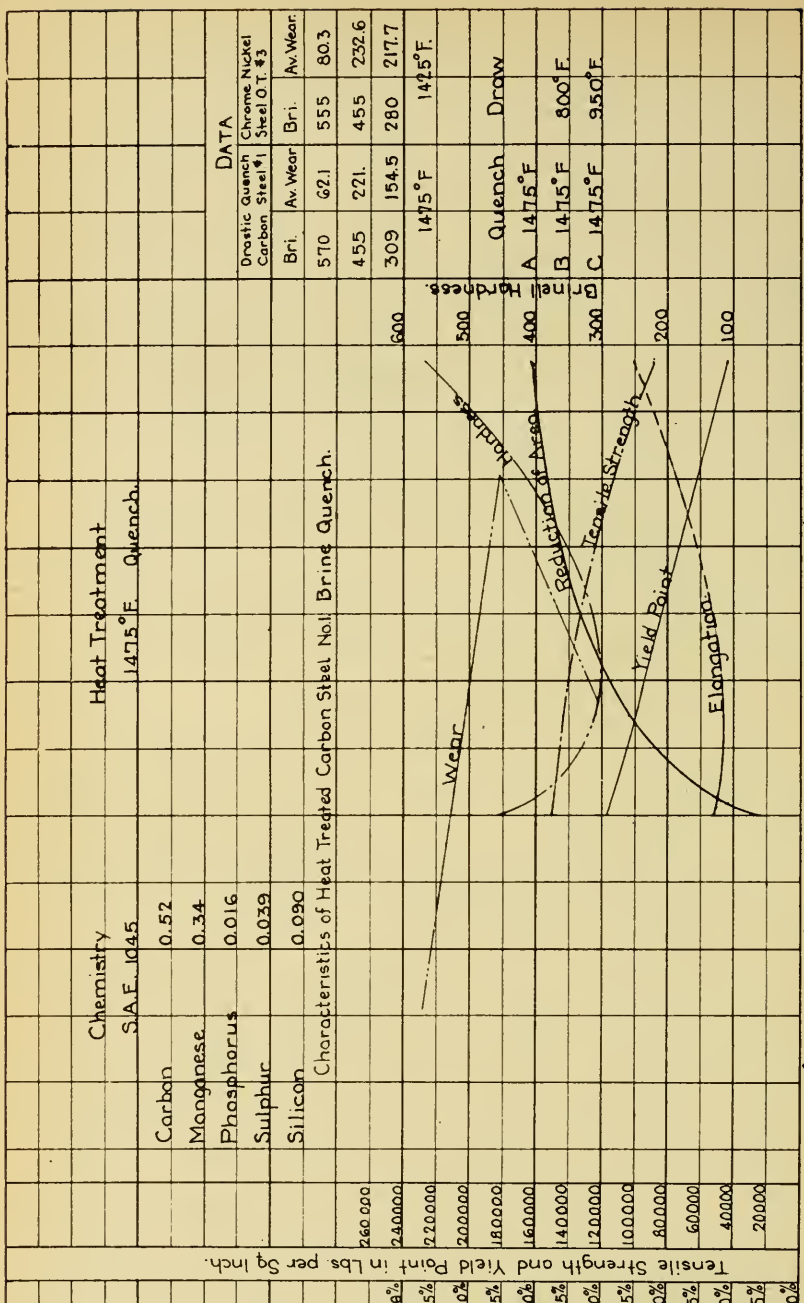

Fig. 7—Curves showing physical properties and wear of plain carbon steel No. 1, brine quenched

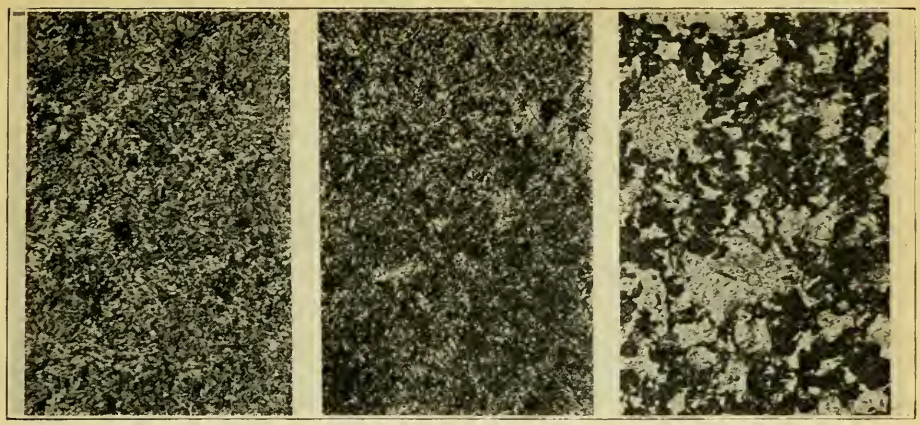

Fig. 8—Microstructure of three specimens of plain carbon steel No. 1. At the left is shown specimen 2A, in the center 2B and at the right 2C

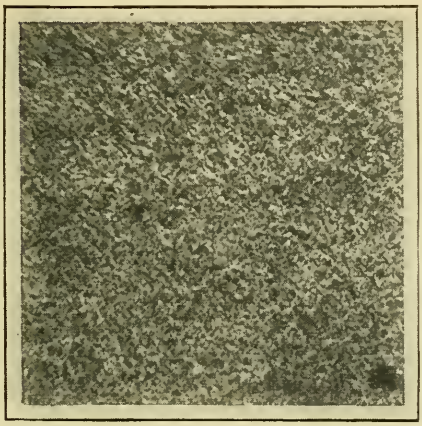

Fig. 9—Microstructure of chrome nickel steel No. 3, specimen 2X. X 100.

No. 3 per revolution of the test rollers. Test roller 3X gave greater weight loss than 1X and 2X. This occurrence has no apparent explanation unless characteristic of the chrome nickel steel. Examination under the microscope disclosed no surface decarbonization or a changed structure. The area covered by steels No. 1 and No. 3 is approximately the same. The structure of test roller 2X is shown in Fig. 9. The structures of 2Y and 2Z showed practically the same structure as 2X.

The curve in Fig. 10 shows the plotted results of the physical properties of steel No. 3 and the average wear loss over the three hardness ranges. Note the wear loss curve is similar to the wear loss curve of the plain carbon steel shown in Fig. 7; increasing at 460 Brinell and decreasing at 302 Brinell.

The curve in Fig. 5 shows the plotted results of the wear loss of steel No. 2 per revolution of the test rollers. The single quenched test rollers gave a slightly better wear than the double quenched test rollers. Photomicrograph Fig. 11 shows the microstructure of the 2S and the 3D test rollers.

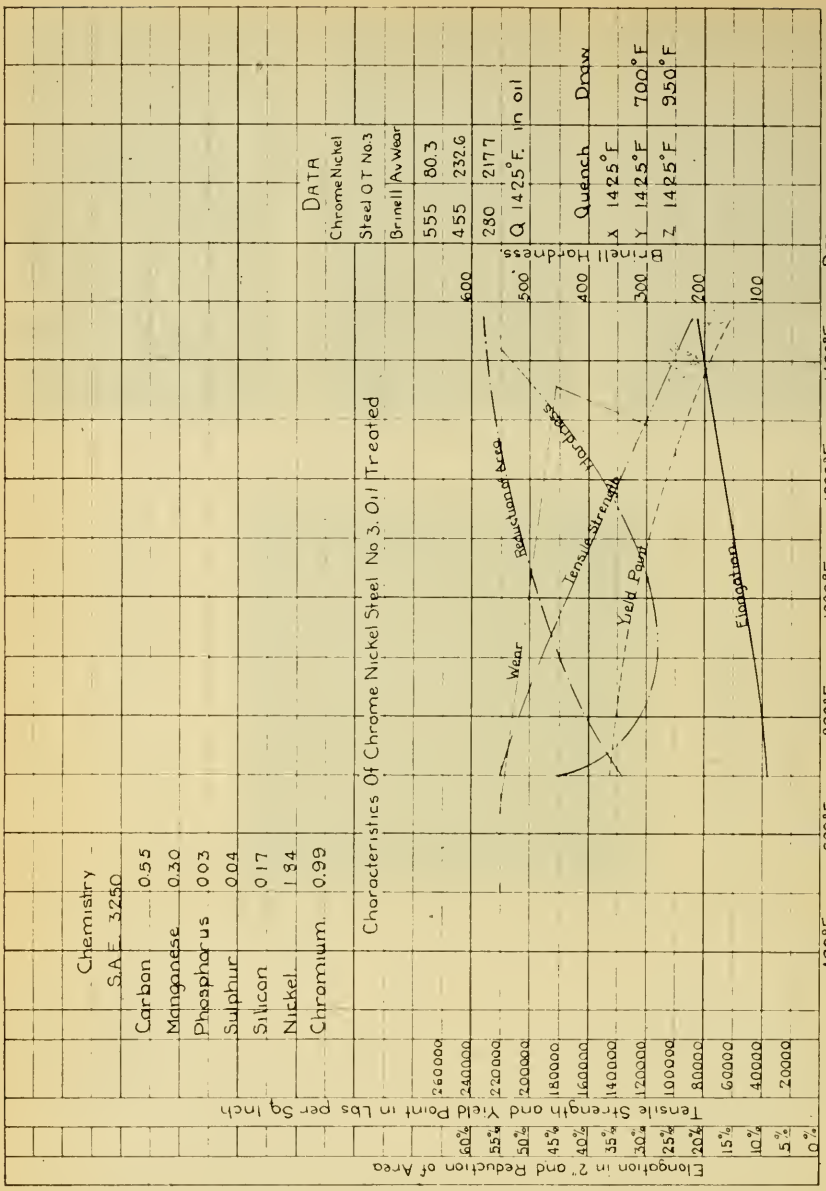

Fig. 10—Curves showing physical properties and wear of chrome nickel steel, No. 3, oil quenched

The curve in Fig. 6 shows the plotted results of the wear loss of steel No. 4 per revolution of the test rollers. Here also the single quenched test rollers gave better wear results than the double quenched test rollers. Photomicrograph Fig. 12 shows the microstructure of the 3S and the 1D test rollers.

In order to get a better perspective of the four steels tested the average wear in milligrams per 18,000 revolutions of the test rollers have been tabulated in Table II. The total linear distance covered by each

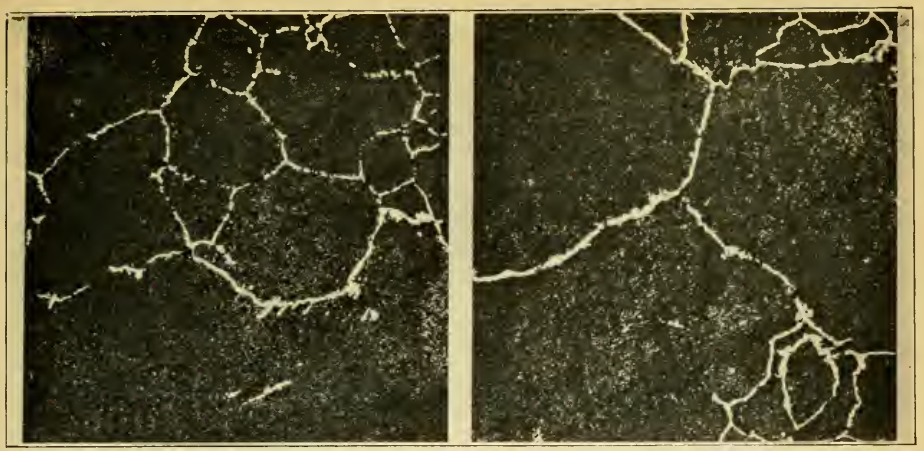

Fig. 11—Microstructure of two specimens of plain carbon steel, case hardened. At the left is specimen 2*S* and at the right is 3*D*

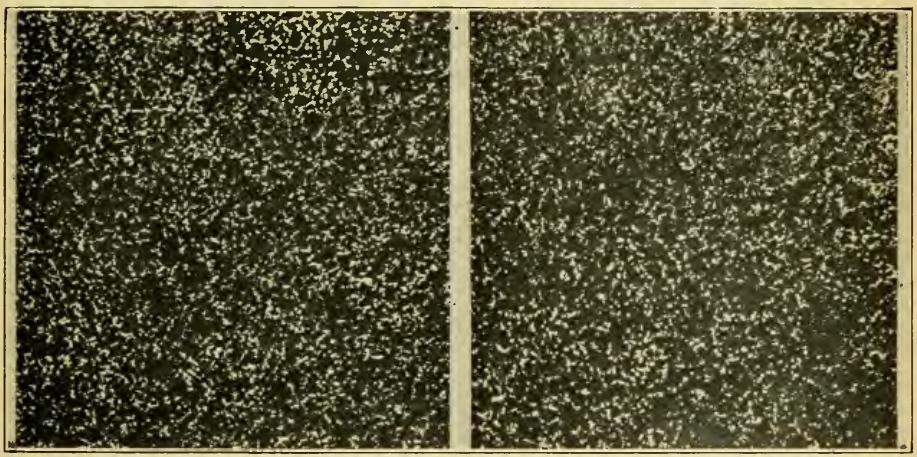

Fig. 12—Microstructure of two specimens of chrome nickel steel No. 4, case hardened. At the left is specimen 3*S* and at the right is 1*D*

test roller was 3.6 miles. The same markings were used so that any one specimen may be followed on the curves or in the tables. The average wear was based on 18,000 revolutions of the test roller so that appreciable amounts of weight loss could be tabulated.

Based on the tests made under the conditions which have been described, the following conclusions are drawn:

1. These tests are preliminary and are published in hope that a more general discussion will be promoted on the properties of metals to determine the relative wear as affected by steels that rub, one against the other.

2. The test results indicate that the greater the density and hardness, the greater the abrasive resistance.

3. The ordinary tension and Brinell tests are not a reliable index to the abrasive qualities of a material.

4. The carbon steels showed more uniform results than the chrome nickel steels and less average wear loss.

5. Further tests will have to be made to determine the combined effect of ductility and hardness on the abrasive properties of materials.

THE CHANGE IN DIMENSIONS OF HIGH SPEED STEELS IN HEAT TREATMENT

By Marcus A. Grossmann

SOME time ago when data was desired on the shrinkage of high speed steel due to heat treatment, a search of the literature failed to reveal any such data. It was, therefore, decided to carry out a series of measurements on high speed steels of three different compositions in common use. The steels were selected from stocks having approximately the following compositions:

	Steel 18 per cent	Steel 15 per cent	Steel 13 per cent
Carbon	0.65	0.65	0.85
Tungsten	18.0	15.0	13.0
Chrome	3.5	3.5	3.5
Vanadium	1.0	0.50	0.50

The property measured was the change in length after heat treatment. The test pieces were cylinders 1½ inches in diameter and about 2½ inches long. They were measured with ordinary 3-inch micrometer calipers. In making the first set of measurements, reported elsewhere ("Shrinkage and Expansion of a High Speed Steel Due to Heat Treatment," M. A. Grossmann, *Chemical & Metallurgical Engineering*, May, 1922), it was found that two precautions should be taken in making length measurements in this way. One, obviously, was to protect the ends of the test pieces from oxidation; the other was to have the planes of the ends parallel, so that the measurements would be concordant even if not taken at exactly the same point on the test piece. The former was accomplished by bolting protecting pieces on the ends of test piece, as shown in Fig. 1. When this was done, about half of the area of the end, at the center, was perfectly clean without a trace of oxidation, although the hardening was done at temperatures up to 2300 degrees Fahr. in an open furnace. The planes of the ends were made parallel by cutting the test pieces in a lathe. The ends of the test pieces and the faces of the protecting disks were then ground smooth, and the resulting surfaces were in sufficiently close contact to keep air from the ends. If the machine work is done carefully, there is no difficulty in keeping the ends clean.

The length of the cylinders was measured in the annealed condition as prepared, then in the quenched condition after hardening, and then after drawing at various temperatures. Care was taken to make all measurements when the test pieces were at approximately the same temperature, about 70 degrees Fahr. The same test pieces were used for the successively higher drawing temperatures after any one quench, but no individual piece of steel was quenched more than once. Three different series of steels were hardened at successively higher temperatures and then drawn and measured. Each series was carried through independently at different times.

The values obtained are given in Tables I, II and III, and a general chart derived from each of these tables is given in Figs. 2, 3 and 4 re-

A paper to be presented at the Pittsburgh Sectional meeting, May 25-27. The author, Marcus A. Grossmann, is metallurgist, Electric Alloy Steel Co., Charleroi, Pa.

Table I

Steel 18. Length of Cylinders After The Heat Treatments Indicated

Quench temp. degrees Fahr.	Dimensions in inches: Original	As quenched	Drawn at 300 degrees Fahr.	Drawn at 500 degrees Fahr.	Drawn at 700 degrees Fahr.	Drawn at 900 degrees Fahr.	Drawn at 1100 degrees Fahr.	Annealed
1900.....	2.5061	2.5060	2.5057	2.5067	2.5066	2.5065	2.5065	2.5056
2100.....	2.5516	2.5519	2.5523	2.5526	2.5525	2.5519	2.5530	2.5511
2300.....	2.5165	2.5180	2.5178	2.5174	2.5169	2.5165	2.5169	2.5159
2000.....	2.5179	2.5189	2.5187	2.5191	2.5181	2.5183	2.5190	2.5185
2200.....	2.4962	2.4989	2.4982	2.4978	2.4970	2.4970	2.4965	2.4964
2300.....	2.5654	2.5675	2.5677	2.5674	2.5669	2.5667	2.5669	2.5661
2400.....	2.4940	2.4968	2.4960	2.4959	2.4949	2.4948	2.4953	2.4957
1900.....	2.5127	2.5138	2.5141	2.5140	2.5139	2.5134	2.5141	2.5130
2100.....	2.3812	2.3840	2.3839	2.3836	2.3831	2.3826	2.3828	2.3825
2200.....	2.5007	2.5036	2.5033	2.5029	2.5023	2.5021	2.5024	2.5016
2300.....	2.5305	2.5332	2.5331	2.5324	2.5321	2.5319	2.5319	2.5321

Table II

Steel 15. Length of Cylinders After the Heat Treatments Indicated

Quench temp. degrees Fahr.	Dimensions in inches: Original	As quenched	Drawn at 300 degrees Fahr.	Drawn at 500 degrees Fahr.	Drawn at 700 degrees Fahr.	Drawn at 900 degrees Fahr.	Drawn at 1100 degrees Fahr.	Annealed
1900.....	2.5211	2.5213	2.5216	2.5223	2.5222	2.5222	2.5223	2.5214
2100.....	2.5056	2.5076	2.5078	2.5081	2.5077	2.5074	2.5074	2.5064
2300.....	2.4951	2.4978	2.4976	2.4973	2.4966	2.4963	2.4977	2.4960
2000.....	2.4872	2.4900	2.4898	2.4897	2.4892	2.4888	2.4891	2.4886
2200.....	2.4951	2.4986	2.4980	2.4979	2.4970	2.4969	2.4984	2.4969
2300.....	2.5169	2.5205	2.5204	2.5193	2.5183	2.5181	2.5185	2.5176
2400.....	2.5107	2.5152	2.5147	2.5145	2.5130	2.5128	2.5134	2.5129
1900.....	2.4610	2.4639	2.4635	2.4634	2.4631	2.4626	2.4635	2.4612
2100.....	2.5084	2.5117	2.5114	2.5109	2.5103	2.5097	2.5102	2.5088
2200.....	2.4987	2.5020	2.5012	2.5003	2.5001	2.4996	2.5007	2.4990
2300.....	2.4967	2.5013	2.5012	2.5007	2.4999	2.4994	2.4997	2.4997

Table III

Steel 13. Length of Cylinders After The Heat Treatments Indicated

Quench temp. degrees Fahr.	Dimensions in inches: Original	As quenched	Drawn at 300 degrees Fahr.	Drawn at 500 degrees Fahr.	Drawn at 700 degrees Fahr.	Drawn at 900 degrees Fahr.	Drawn at 1100 degrees Fahr.	Annealed
1900.....	2.5185	2.5234	2.5231	2.5230	2.5225	2.5207	2.5205	2.5198
2100.....	2.4898	2.4920	2.4913	2.4936	2.4925	2.4917	2.4925	2.4894
2300.....	2.4406	2.4426	2.4419	2.4413	2.4428	2.4424	2.4433	2.4395
2000.....	2.5269	2.5301	2.5290	2.5291	2.5287	2.5284	2.5285	2.5261
2200.....	2.5175	2.5215	2.5210	2.5197	2.5195	2.5190	2.5201	2.5176
2300.....	2.5377	2.5414	2.5402	2.5398	2.5389	2.5385	2.5402	2.5382
2400.....	2.5432	2.5464	2.5452	2.5444	2.5435	2.5433	2.5454	2.5441
1900.....	2.4889	2.4916	2.4905	2.4901	2.4905	2.4898	2.4903	2.4872
2100.....	2.5128	2.5160	2.5149	2.5139	2.5143	2.5137	2.5144	2.5120
2200.....	2.5213	2.5242	2.5238	2.5233	2.5231	2.5225	2.5234	2.5214
2300.....	2.5022	2.5057	2.5045	2.5039	2.5030	2.5025	2.5045	2.5025

spectively. Examination of the table and the charts reveals that high speed steels of this type always expand in hardening. In general, up to a certain limit, the higher the hardening temperature the greater will be the expansion. When this hardened high speed steel is drawn, it contracts at temperatures up to 900 or 1000 degrees Fahr. When heated then at 1100 degrees Fahr. it expands and when finally heated at higher temperatures it contracts until it finally reaches approximately the original dimensions of the annealed condition.

Careful examination of the table will show that there is in some cases a notable variation in the amount of change of dimension. This is due partly to the fact that the earlier measurements were not so accurate as the later ones. However, these variations in dimension change are due

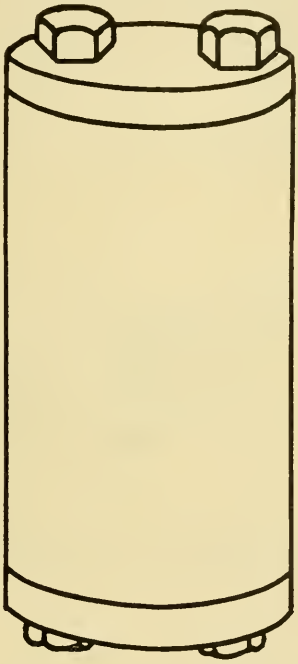

Fig. 1—Full size sketch of test specimen used

in probably greater degree to slight variations in the heat treatment. It seems likely that the time factor is the one which has the greatest effect on these variations. Greater concordance in individual results could undoubtedly have been obtained by timing all heat treating operations accurately, combined with greater care in the use of salt baths, but these refinements were purposely avoided. It was the desire to obtain average data which would show the order of magnitude of the changes to be expected when operating under average shop conditions. The charts are drawn to show the results likely to be obtained on the average, when treating steel under the conditions shown.

It will be observed that there is always an expansion on hardening, and that this expansion is greater, the higher the quenching temperature, up to a certain point. The subsequent contraction on heating up to 900 degrees Fahr. is also greater the higher the quenching temperature. This

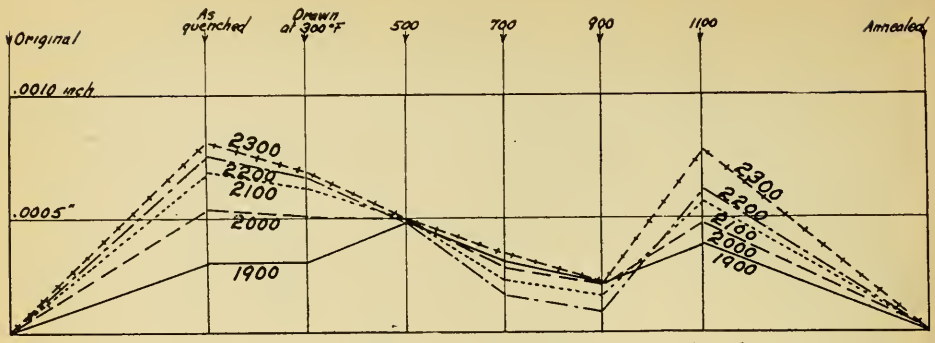

Fig. 2—Steel 18. Increase in length per inch of length under various heat treatments

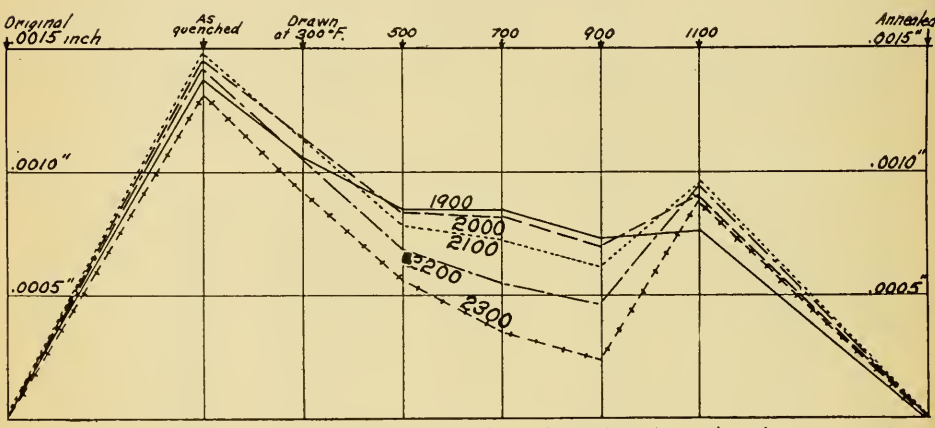

Fig. 3—Steel 15. Increase in length per inch of length under various heat treatments

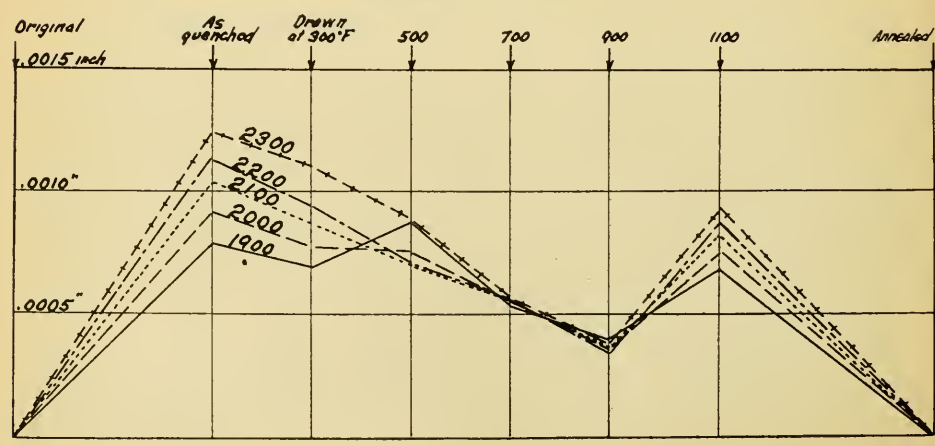

Fig. 4—Steel 13. Increase in length per inch of length under various heat treatments

is to be expected, as the original expansion has to do largely with the formation of one form of martensite. This martensite is changed by tempering, the resulting grain growth and formation of carbide being accompanied by contraction in volume. Then when the steel is heated at 1100 degrees Fahr., an expansion sets in, which is the index of the change from austenite to the second martensite. This, as was also to be expected, is more pronounced the higher the quenching temperature. With further drawing at still higher temperatures the steel contracts to about its former dimensions.

A comparison of the three steels, shows that the first expansion is greater in the lower tungsten steels, and that the second expansion, namely at 1100 degrees Fahr., is greater in the higher tungsten steels. A further important point is that while the lower tungsten steels can be heat treated to develop a reasonably large amount of austenite, the heating in the highest ranges causes overheating, coarse grain, and its accompanying brittleness with excessive blistering of the surface. The higher tungsten steels can be heated to temperatures high enough to develop a very considerable amount of austenite, and still retain a fine-grained structure with its accompanying advantages.

THE INFLUENCE OF HEAT TREATMENT UPON THE MAGNETIC PROPERTIES OF STEEL

By Lancelot W. Wild

MAGNETIC quantities that may be varied by subjecting steel to definite heat treatments may be classified as follows:

1. The intensity of magnetization under the influence of a magnetizing force sufficient to saturate the steel.

2. The permeability under one or more purely arbitrary magnetizing forces.

3. The residual induction on closed circuit, resulting from the application of any conveniently high magnetizing force.

4. The coercive force resulting from the application of a high magnetizing force.

Intensity of magnetization when the steel is fully saturated is a measure of the amount of magnetizable material in the steel. It can be measured with a high degree of precision on short cylindrical specimens and the measurements can be carried out very quickly.

Measurement of permeability, if it is to be measured with precision, requires the employment of specimens of ring form or else very long rods which must be tested in pairs. Rings require that they be wound for each test and the employment of long rods greatly increases the difficulty of carrying out precise heat treatment.

Measurement of residual magnetism is even more difficult than that of testing permeability. It is hardly possible to obtain precision except with ring specimens.

Coercive force can be measured on the same cylindrical specimens as are used for the measurement of intensity of magnetization. The testing can be carried out very quickly and a high degree of precision is obtainable.

In this paper the author has confined his attention to the measurement of intensity of magnetization and coercive force, the two tests being carried out on the same set of specimens. The object of the experiments was to obtain a general survey of the effects of reheating hardened steel to various temperatures and slowly cooling it.

The specimens consisted of cylinders 1 inch long and ¼ inch in diameter. The magnet for saturating the specimens was formed out of two discarded transformers. The magnet with the specimen in position is shown in section in Fig. 1. *a* is the specimen under test. *b* is the ballistic coils, of which more will be said later, *c* is a block of ebonite, into which the specimen is inserted. This insures that the specimen shall stand upright while the upper half of the magnet is being lifted on or off. *d* shows the winding of the magnets. *e* represents the two blocks of iron. These were made about 0.995 inches high in order that the weight of the upper half of the magnet should rest mainly upon the specimen so as to secure good magnetic contact. *f* represents the transformer laminations. The section of the core is 2 inches square, thus giving 4 square inches of pole surface.

The magnet was wound with 820 turns of copper wire of 0.080 inch diameter. With 12 amperes and about 20 volts a magnetizing force of $H = 4000$ was obtained. With 30 amperes H could be increased to 6000, but

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A paper presented by title at the Indianapolis Convention. The author, Lancelot W. Wild, is president, Wild-Barfield Co., London, Eng.

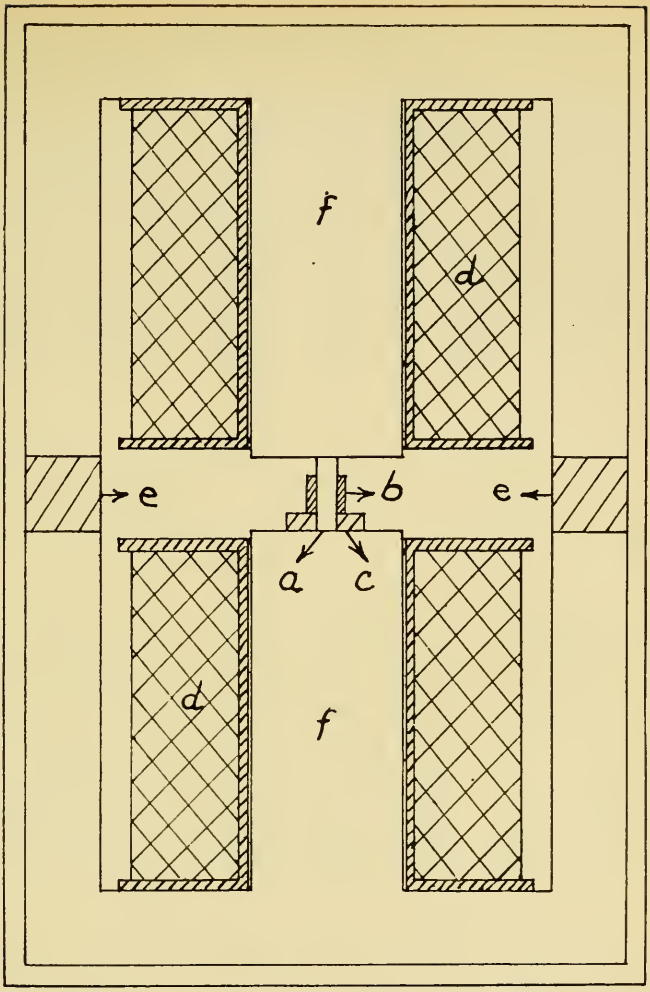

Fig. 1—Cross Section of Testing Apparatus Showing Magnet and Specimen in Position.

Table I
Density and Composition of Specimens

	SCI	MS	A	B	D	W	WPS	N
Density	7.80	7.80	7.75	7.75	7.70	8.10	7.52	7.75
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Carbon	0.03	0.12	0.63	0.91	1.03	0.86	1.24	0.42
Manganese ...	0.04	0.625	0.33	0.34	0.29	0.345	1.05	0.65
Tungsten	...	...	...	...	...	6.34	...	...
Chromium	...	...	...	...	...	...	10.6	...
Nickel	...	...	...	...	...	...	...	3.58
Silicon	0.01	...	0.094	0.094	...	...	...	...
Sulphur	0.013	...	0.008	0.017	...	...	...	...
Phosphorus ..	0.014	...	0.017	0.072	...	...	...	...

owing to the heat produced it was found impossible to use this higher magnetizing force except for one experiment per day. The winding was not in any way endangered by using the larger current, but sufficient heat was soon communicated to the specimens to make a measurable drop in their saturation intensities. Fortunately, it was found that every steel tested was fully saturated at $H=3000$, and most of the testing was carried out at $H=4000$, under which conditions the specimens remained quite cool.

Arrangement of the ballistic coils the author believes to be novel. An inner coil of 40 turns was wound directly without any insulation beyond the silk covering of the wire itself in a single layer on a very thin brass tube. An outer coil wound with 18 turns and made in the same way was fitted concentrically onto the inner coil. The two coils had exactly the same area turns. The two coils were connected differentially in series with a ballistic galvanometer, which was scaled in terms of maxwell turns.

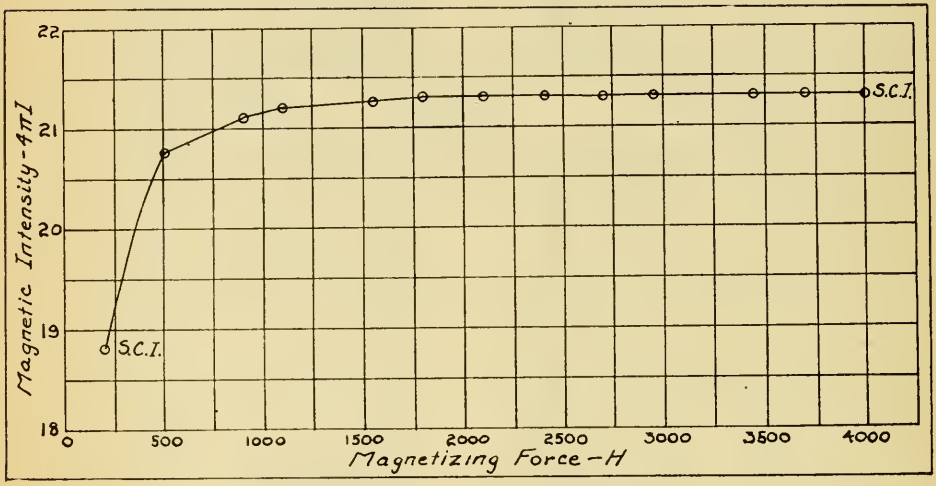

Fig. 2—Magnetization Curve for Swedish Charcoal Iron

When a brass dummy specimen was placed between the magnet poles and the magnetizing current was reversed, absolutely no throw was obtained on the galvanometer. However, when a magnetizable specimen was placed in position and the current was reversed a galvanometer throw was obtained which it is evident must be proportional to, not the induction in the specimen, but the magnetic intensity.

$$2^{\pi}I=\frac{Mt}{2A \times (T_1-T_2)}$$

Where I is the magnetic intensity.
A is the area of the specimen.
T_1 is the number of turns on the inner coil.
T_2 is the number of turns on the outer coil.
Mt is maxwell turns.

Two advantages are found in using this differential arrangement. In the first place, it is not necessary to maintain the current steady. In the second place a higher precision is obtainable by taking a single throw instead

of the more usual plan of taking one reading on the inner coil and subtracting from this an amount calculated from a reading taken with the two coils connected differentially.

To obtain the value of H, which however was never required with exactness, a throw was taken on the outer coil alone and from this was subtracted an amount derived from the ordinary differential throw by multiplying it by 18 and dividing by 22, the ratio of the turns on the outer coil to the effective differential turns.

Fig. 2 shows the magnetization curve obtained with a very pure Swedish charcoal iron (SCI). The density of this iron was 7.80. It will be seen that saturation is attained at about H=1800, and that above this value the magnetic intensity remains constant. The saturation value of $4\pi I$ is 21.3 kilo lines per square centimeter and I itself is therefore 1695.

The following values have been found previously:

Authority	Year	Value of I
Ewing and Low	1889	1630-1740
Du Bois	1890	1700-1725
Gumlich	1909	1725
Peirce	1909	1740
Beattie	1910	1740
Wild	1910	1695-1710
Hopkinson	1911	1680
Cheney	1920	1672-1725

The variation in the above authorities is remarkable. No doubt this is partly due to errors of method and of instrument calibration, but is also no doubt very largely due to variations of density and to slag inclusions.

The coercive force was measured on the same specimen pieces as were used for the saturation intensity test. The procedure was as follows: After magnetizing the specimen, the upper half of the magnet was lifted off and the specimen was removed and placed in a small search coil connected to a ballistic coil of suitable sensitiveness. The specimen was then sharply withdrawn and the galvanometer throw was observed. This gave the open circuit remanance from which the coercive force could be calculated directly.[1]

$$Hd = \frac{Mt}{4\pi AT} \times D$$

Where B=flux density.
A=area of specimen in square centimeters.
Mt=maxwell turns.
T=number of turns on search coil.
Hd=demagnetizing force due to ends.
Hc=coercive force.
D=demagnetizing coefficient.

The value of D depends upon the dimension ratio that is length to diameter. In this case the dimension ratio was 4. The value for D for this dimension ratio is given by Professor Thompson[2] as 0.724.

Now Hc must be more than Hd or there would be no open circuit remanance. For a specimen having a dimension ratio of 4 a cursory in-

1. L. W. Wild. "A Method of Measuring the Magnetic Hardness of Ferrous Metals and Its Utility for Carrying Out Research Work on Thermal Treatment." Transactions of the Farraday Society. Vol. 15, Part 3.
2. Silvanus Thompson. "The Magnetism of Permanent Magnets." Journal of the Institution of Electrical Engineers. Vol. 50. No. 217.

spection of a hysteresis loop shows that the ratio of *Hc* to *Hd* must be something less than 1.05. Experiments on tungsten steel have determined this ratio to be 1.02 with an uncertainty of about 0.01 either way. This is quite near enough for the measurement of coercive force, for heat treatment experiments, especially as relative rather than absolute values are required.

Experiments were carried out on iron and 7 different steels. The analyses and density of these is given in Table I. The specimens were first heated and quenched from the following temperatures:

S.C.I.—Swedish charcoal iron. 910 degrees Cent.

M.S.—Common mild steel. 860 degrees Cent.

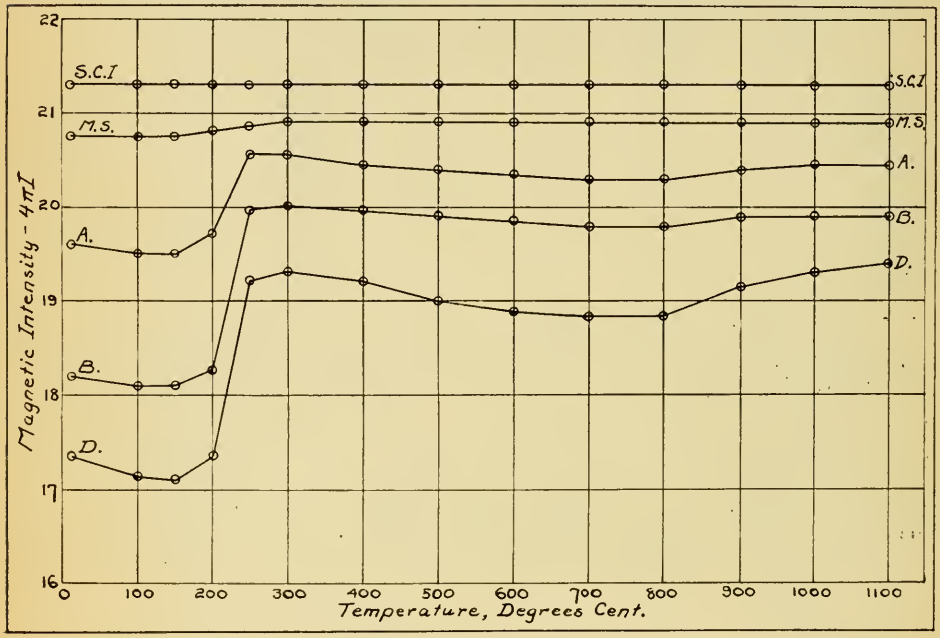

Fig. 3—Magnetic Intensity Curves for Swedish Charcoal Iron, Common Mild Steel, and Straight Carbon Steels

A, B, and D.—Straight carbon steels. When just nonmagnetic.

W. and W.P.S.—Tungsten and chrome steels respectively. 850 degrees Cent.

N.—Nickel steel. When just nonmagnetic.

After being quenched the specimens had 24 hours rest before being tested for saturation intensity and coercive force. The specimens were then subjected to the following successive heat treatments being tested after each when quite cold.

1. Boiled in water for 5 hours.
2. Heated in oil and maintained at 150 degrees Cent. for 30 minutes.
3. Heated in oil and maintaianed at 200 degrees Cent. for 5 minutes.
4. Heated to 250, 300 and 400 degrees Cent. successively in a mixture of potassium and sodium nitrates.
5. Heated in furnace in an atmosphere of pure hydrogen to temperatures of 500, 600, 700, 800, 900, 1000 and 1100 degrees Cent. They were

cooled down in the furnace to 400 degrees Cent. and were then removed and finished in air.

Table II gives all the values of magnetic intensity and Table III those of coercive force. Curves from these tables have been plotted and are to be

Table II
Values of Magnetic Intensity*

Reheating temperature degrees Cent.	SCI	MS	A	B	D	W	WPS	N
None	21.3	20.75	19.6	18.2	17.35	18.45	14.25	20.7
100	21.3	20.75	19.5	18.1	17.15	18.45	14.2	20.7
150	21.3	20.75	19.5	18.1	17.1	18.45	14.2	20.7
200	21.3	20.8	19.7	18.25	17.35	18.5	14.25	20.75
250	21.3	20.85	20.55	19.95	19.2	19.15	14.3	20.8
300	21.3	20.9	20.55	20.0	19.3	19.3	14.35	20.9
400	21.3	20.9	20.45	19.95	19.2	19.3	14.35	20.8
500	21.3	20.9	20.4	19.9	19.0	19.2	14.35	20.75
600	21.3	20.9	20.35	19.85	18.9	19.15	14.35	20.7
700	21.3	20.9	20.3	19.8	18.85	19.15	14.35	20.6
800	21.3	20.9	20.3	19.8	18.85	19.25	14.35	20.55
900	21.3	20.9	20.4	19.9	19.15	19.6	14.45	20.7
1000	21.3	20.9	20.45	19.9	19.3	19.4	14.4	20.75
1100	21.3	20.9	20.45	19.9	19.4	19.15	14.35	20.75

*Specimens heated and quenched from best hardening temperature, then reheated to following temperatures and slowly cooled. $4\pi I$ tested when quite cold.

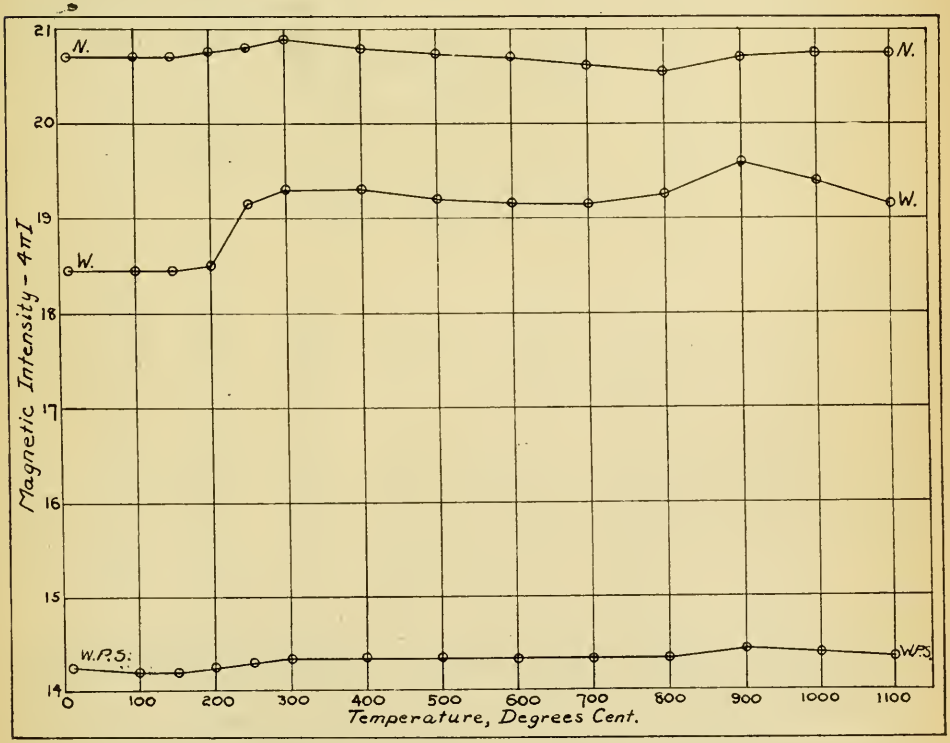

Fig. 4—Magnetic Intensity Curves for Nickel Steel, Tungsten Steel and Chrome Steel

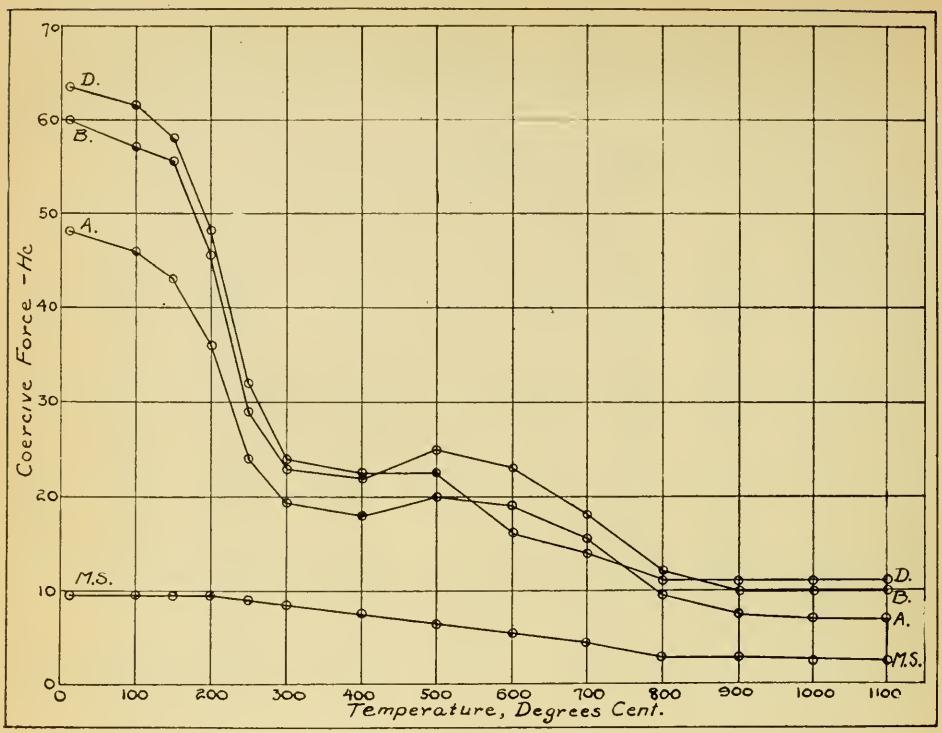

Fig. 5—Coercive Force Curves for Common Mild Steel and Straight Carbon Steels

Table III
Values of Coercive Force*

Reheating temperature degrees Cent.	SCI	MS	A	B	D	W	WPS	N
None	1.5	9.5	48	60	63.5	61.5	48.5	24
100	1.5	9.5	46	57	61.5	58	48	23
150	1.5	9.5	43	55.5	58	55	47	22
200	1.5	9.5	36	45.5	48	45	45	21
250	1.5	9	24	29	32	33	43	18.5
300	1.5	8.5	19.5	23	24	26	40	15.5
400	1.5	7.5	18	22	22.5	24.5	37	13.5
500	1.5	6.5	20	25	22.5	23	26	10
600	1.5	5.5	19	23	16	24.5	17	9
700	1.25	4.5	15.5	18	13	20	15	10.5
800	1.0	3	9.5	12	11	16	14.5	8.5
900	1.0	3	7.5	10	11	15	14.5	7.5
1000	0.75	2.5	7	10	11	21	22	7
1100	0.75	2.5	7	10	11	27	30	7

*Specimens heated and quenched from best hardening temperature, then reheated to following temperatures and slowly cooled. Coercive force measured when quite cold.

found in Figs. 3 to 6. It will be seen that the saturation intensity of iron remains quite unaffected by heat treatment, though the coercive force de-

clines as soon as hardening strains are taken out and still further as grain growth commences.

The galvanometer employed was not sufficiently sensitive to bring out the changes that really occur in the coercive force of iron. This might advantageously form the subject of a separate investigation. The addition of carbon lowers the saturation intensity all along the line but there does not appear to be a directly linear relationship between the magnetic intensity and the carbon content. The most notable feature of the carbon steels is the rise of magnetic intensity between 200 and 300 degrees Cent., when the cementite is precipitated from solution.

The small drop of magnetic intensity on reheating to 100 or 150 de-

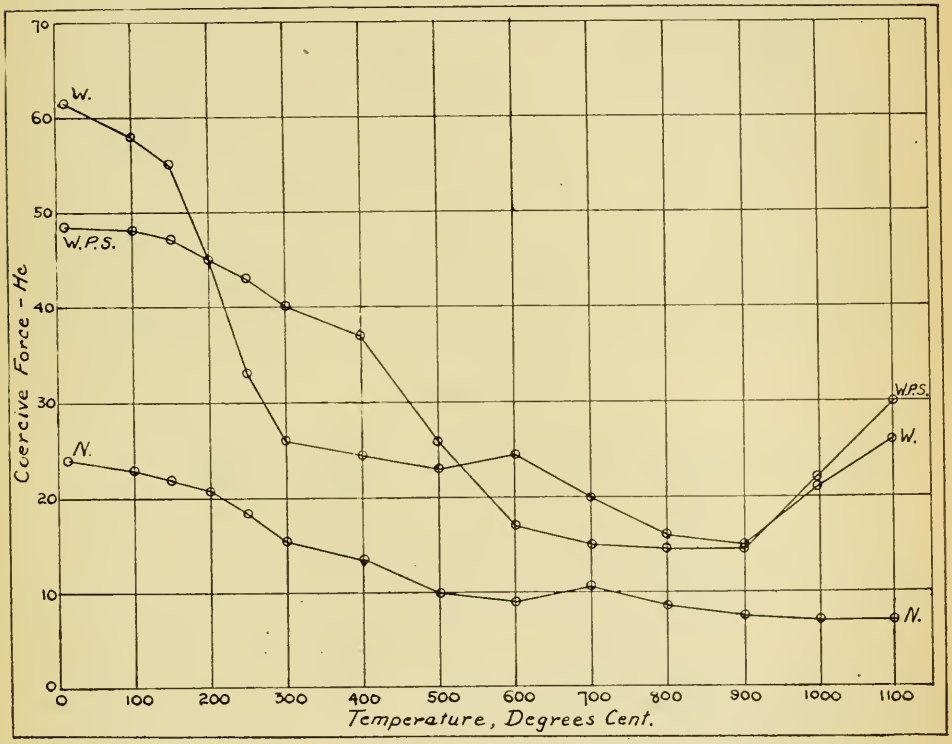

Fig. 6—Coercive Force Curves for Chrome Steel, Tungsten Steel and Nickel Steel

grees Cent. the author is unable to explain. On reheating to a temperature of 400 to 800 degrees Cent., apparently some of the cementite returns into solution and does not entirely reprecipitate with slow cooling. On reheating to 1000 degrees Cent. or more when all cementite must be in solution, apparently all precipitates on slow cooling.

Referring to Fig. 5, it will be seen that there is a very large drop of coercive force taking place between 200 and 300 degrees Cent. Doubtless, this is due to the cementite coming out of solution and thereby becoming magnetic. The peculiar hump at a temperature of 500 degrees Cent. is of interest. This may be due to the cementite again partially entering solution and not precipitating on cooling as previously suggested.

Coming to the three alloy steels, it will be seen that the nickel steel

behaves in very much the same way as a carbon steel. The nickel however which, when in a free state is only about one-third as magnetic as iron, becomes about equivalent to iron when alloyed with it. The tungsten steel follows the general line of a carbon steel except that the carbon features are less pronounced and there is a decided drop of magnetic intensity and increase of coercive force when a reheating temperature of 900 degrees Cent. is exceeded.

The chrome steel is most remarkable. It contains 87 per cent of iron and yet the saturation intensity is only about 67 per cent of pure iron, and this remains almost untirely unchanged by heat treatment. The coercive force does not drop on tempering nearly so steeply as with other steels, and the rise on heating to over 900 degrees Cent. is even more pronounced than with tungsten steels. It will be noticed that all three alloys steels show a distinct hump in their coercive forces, the chrome steel at 400, the tungsten steel at 600 and the nickel steel at 700 degrees Cent.

It is hoped that a consideration of these results will be of some value to metallurgists in coming to definite conclusions as to what really happens when steel is hardened or otherwise given thermal treatment.

The author wishes to acknowledge his indebtedness to his brother Roland C. Wild for carrying out numerous analyses, to Sir Robert Hadfield for supplying him with a sample of very pure iron and for taking an interest in the work, and to numerous previous experimenters and writers, notably the late Prof. Silvanus Thompson and the late Prof. Bertram Hopkinson, who by their work and publications have done much to clear the way.

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THE CARBONIZING PROCESS—RELATION OF TIME AND TEMPERATURE TO DEPTH OF CASE

By Theodore G. Selleck

THE time factor of the carbonizing process is one that depends upon so many conditions outside of itself that it really seems under most circumstances to be incidental to the process, rather than a positive, predetermined factor. Of course all action of whatever sort is measured and usually more or less governed by time. In most chemical and mechanical processes this factor is thoroughly understood and is given a scientific basis of value; but in the carbonizing process we find it difficult to establish its value because such value depends upon so many conditions which, so far, we have not been able to even standardize approximately.

First of all in carbonizing, the time required to produce a certain depth of case will depend upon the degree of temperature at which the operation is carried out. To the average case hardener this settles the whole question of the function of time. He is convinced that if he gives his work 100 per cent more time he will much more than double the depth of penetration without increasing the temperature. If he could maintain the same conditions for the extended time that prevailed during the shorter period, his conclusions probably would prove quite true, and oftentimes this occurs. Again he may be surprised to find that his conclusions are all wrong, and that he has not added to depth of case to any material extent by giving added time. In some cases he really loses in the quality of the case. This is because time, as an element of the process, depends not only upon temperature but upon every other element or factor of the process and the conditions of those elements and factors. Some of them are exceedingly variable, changing during the progress of the operation without giving the operator any evidence of change until he finds it in the final result.

Carburizing materials sometimes change their chemical compositions materially during protracted periods of heating, and the operator has no knowledge of a change until he finds no increase of penetration. Probably he finds also that the carbon content of the case is lower than he has been in the habit of obtaining in the shorter operations.

This sometimes occurs where an operator has used one carburizer, perhaps for years, on a certain line of work requiring only short time periods and he has found it to work satisfactorily and consistently at a certain temperature for a certain period of time. Suddenly he changes his time schedules, or his temperature, and finds that either the added time or the increased temperature have brought about chemical changes in his carburizer that he did not anticipate.

It is not unusual either for one user of a carburizer to obtain greater depth of case than another user of the same carburizer, when used for the same period of time, at the same temperature, on the same type of steel and on the same character of parts. In the one case the operator may be getting as much as 1/16-inch penetration in 6 hours at 1650 degrees Fahr., while his neighbor may be getting but 1/32-inch in the same time and at the same temperature. The governing conditions in such cases may be in the difference in the methods of packing the parts in the boxes,

The author, Theodore G. Selleck, is a consulting metallurgist, 302 N. Pine Ave., Chicago. This is the third of a series of 10 articles on "The Carbonizing Process" written by Mr. Selleck.

or pots, or the placing of the boxes, or pots in the furnace. These are some of the variables of the process which affect directly the value of time in the process and make it difficult to establish standard schedules, or to find the true relation of time to temperature in carbonizing steel. It would not be difficult for us to find the exact relation of time to temperature could we always be sure that we had the exact temperature the pyrometer indicated. If we knew exactly the carbon content, the percentage of other alloys in the metal; and could be sure of the constancy of the carburizer. These "ifs" form a barrier that we have been unable to remove by any method of operation that has been developed to the present time. Therefore it is only in a general way can we consider the relation of these two factors of the process to each other, and to the results to be obtained in the application of the process.

As a matter of fact there is no element of time in the carburization

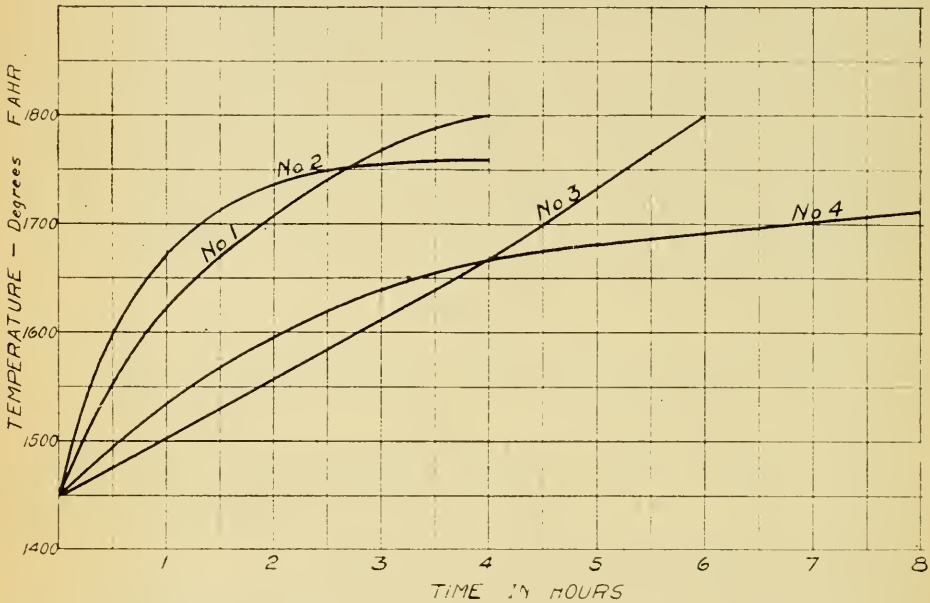

Fig. 1—Chart showing carbon penetration with relation to time and temperature

of iron, when the metal has been brought to the proper thermal condition and the carbon is simultaneously in the proper condition for the iron to accept it. The carburization is instantaneous under such conditions, although its permanency may depend upon conditions that are difficult, if not impossible to establish.

The writer has seen numerous examples of steel castings carbonized by the use of a "carbonizing core" during the pouring of the metal; and it is quite possible to obtain considerable depth of case by this method. However, the difficulty lies in preventing the "burning out of the carbon" during the pouring operation. But it is evident that the carburization must be instantaneous. T. E. Worley, of the American Steel Foundries Co., of Hammond, Ind., has made some very interesting experiments along the line of carbonizing steel castings in the pouring of them.

Another method of proving the instantaneous action of carburization

is to heat the metal to a temperature well beyond its critical point and to cover it with such carbonaceous materials as charred leather, charcoal, barium, etc., all finely powdered. A high carbon content is obtained in this manner, and because of the fact that the temperature of the metal falls rapidly and is below the carbonizing temperature within a few minutes, the carburization must be instantaneous. The element of time therefore applies only to the travel of the carbon from the surface of the metal toward the center or core. This travel depends upon (1) temperature, (2) character of the metal, (3) the nature and constancy of the carburizer.

Some years ago the writer made some experiments to determine the exact relation of temperature, or rather heat, to the absorption of carbon in the carbonizing process. The theory upon which these experiments were based, was that the same number of heat units passing through steel surrounded by carbonaceous material and at a temperature above the carbonizing point of the steel, should always produce the same result, regardless of the time involved in the operation. Several tests were made and charted, but unfortunately the experiments were never carried to a conclusion, although some data of value was obtained.

In the making of these tests to establish, what the writer has called a "thermo-volumetric scale" of heat values, various curves were made of carbonizing operations carried on always at rising temperatures, never at certain temperatures for a definite time period. These curves and the results obtained in their making were compared from the standpoint of the number of the heat units used in their development. One of the charts is shown in Fig. 1. Curves No. 1 and 2 show the same penetration for the same time period, although temperature conditions were different for the two tests during the operation. The same result, so far as depth of case, was obtained in the making of curves No. 3 and 4, although No. 4 had the highest temperature for the first three hours and was given the advantage of two more hours of heat. The number of heat units cannot be stated because the records of these experiments have been lost. But it will be noticed that no record is made of the heat involved below the minimum carbonizing temperature of 1470 degrees Fahr.

In a positive manner these results seem to establish the relation of time to temperature to be the same as indicated in Fig. 2, wherein a graphic illustration of the difference in the value of the two factors is shown. This chart was made from tests of carburizing operations carried on for stated periods under temperature and carburizer conditions as constant as possible. The same carburizer was used, the same type and size of steel test pieces were used, the same alloy container was used, and the same furnace and pyrometer used in all the tests. An interesting, and valuable chart could be developed by carrying this line of experiments further, but from this chart it will be seen that a few more degrees of temperature is vastly more potent in producing depth of case than several hours time. According to this chart the line of tests run at 1700 degrees Fahr. gave the following depths of penetration for the periods of time mentioned:

Carburizing Time hours	Depth of Penetration Inches	Increase Per cent
2.5	$\frac{1}{64}$	100
5	$\frac{1}{32}$	
8	$\frac{1}{16}$	100
10	$\frac{5}{64}$	25
12	$\frac{7}{64}$	40

At a temperature of 1750 degrees Fahr. a penetration of 5/64-inch was obtained in six hours, as against 10 hours for the lower temperature, whereby it is seen that the potency of 50 degrees above 1700 degrees Fahr. is equal to four hours at 1700 degrees Fahr. The vertical line on the chart indicating a series of tests carried for a period of six hours at various temperatures indicates that 1/32-inch penetration was obtained in six hours at 1600 degrees Fahr. whereas the horizontal line shows that the same depth of case was produced in five hours at 1700 degrees Fahr.

From these charts we learn that if all desired is heavy penetration we have only to carbonize at a high temperature, but it is a foolhardy case hardener who adopts that method without determining first of all the carbonizing efficiency of his steel before attempting to establish time schedules. Facts concerning the carbonizing efficiency of the various alloys added to steel were given in the last paper of this series, published in the August, 1921, issue of TRANSACTIONS, therefore the matter will not be taken up here.

It has been stated that the travel of carbon into the steel from the surface toward the core, depended upon three conditions, the first of which has been discussed. However, it may be said in addition, that for the best

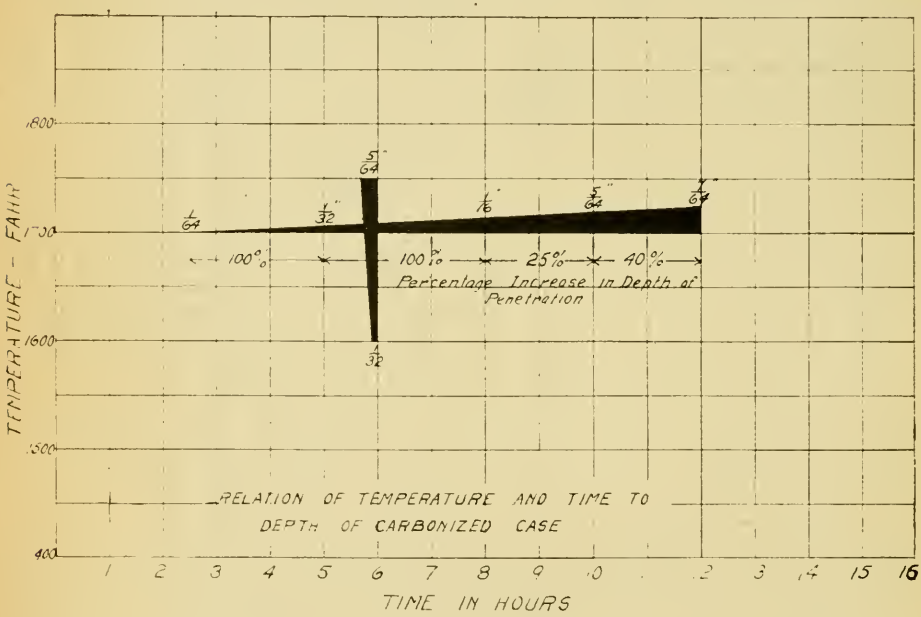

Fig. 2—Chart showing relation of temperature and time to depth of case

results in carbonizing, it is better to have a rising temperature throughout the operation than to have the temperature drop at any time even for a brief period, as such a drop of temperature, if of any consequence, will affect materially the diffusion of the carbon. Further light has been thrown upon the case mentioned in the August, 1921, issue of TRANSACTIONS concerning the plug gages that spalled severely when quenched from the pot. It seems that analysis of the scale from these gages showed a carbon content far beyond the theoretical capacity of the metal to absorb carbon, and that during the process of carbonizing, a severe

drop of temperature occurred which interfered with the natural diffusion of the carbon into the metal.

Character of the steel placed in the hands of the case hardener is at times only approximately known to him and as a result he is frequently the victim of circumstances. In the regular run of business in the treating of standard parts it is possible for him to know closely the analysis of his metal and accordingly he should be able to judge whether higher temperature or longer time is best for any added penetration desired. He may be assured that under all conditions of metal the higher the temperature the more rapid will be the penetration, but the good workman will know whether it is wise to use it.

As every case hardener should know the character and the carbonizing efficiency of the steel he treats, he should also know the efficiency of his carburizer. He should know, by personal experience, and not by the claims of the salesman or manufacturer whether it is of a character that will remain constant during long hours of service, or whether it has a limit beyond which it will not be efficient and economical. In determining these matters he should not take others word for it, not even the laboratory of his own plant, because no manufacturer knows as he does the exact conditions under which he is working, and laboratory conditions are rarely those of the furnace room. The man on the job is the one who above all others should know his equipment, his tools, his help, his supplies and his results better than anyone else, and the knowledge he gains from actual test and experiment is more valuable than he can gain by advice from metallurgist, salesman, or even by reading these articles, provided he is broad enough to take the best that is offered him by these agencies and add them to his own personal experiences to profit thereby.

DETERMINATION OF HEAT TREATING COSTS

By Harold F. Wood

DURING the past few years we have been passing through a period of large production and of general industrial waste. This has resulted in but little attention being paid to the question of costs. As long as there was a demand for the products, the main item of consideration was how to produce more. This resulted in a decrease in the efficiency of labor and a general increase in the amount of avoidable waste. Such a policy on the part of industrial managers created wasteful ideas not only on the part of labor but also on the managers themselves.

In those days the cost department served as a tool to collect unreliable data from which to secure figures to convince the customer that he should pay more for his product rather than to collect accurate data to convince the shop that the cost of production was excessive.

We have this past year been passing through a period of industrial depression. According to the opinion of our best business experts, we are now just entering a period of industrial readjustment which, in turn, will be followed by a period of general business prosperity. Just how soon this period of prosperity will arrive and how prosperous it will be, will be determined by how long it takes everyone connected with business to readjust themselves to the new conditions and get away from their wasteful and costly methods employed during our recent production period.

The industrial concern that realizes these facts and that knows accurate costs of every detail making up the final cost of its product will be the concern that will survive and prosper. Its motto will be "How to produce the most and the best for the least." This paper will not attempt to discuss how to produce the "most and the best" but will show in detail the items to be considered in the determination of an accurate unit cost and how these various items are embodied in the final cost which in turn tells us whether we are producing the "most and best for the least."

The heat treating department has come into its own and its operations of today constitute an important item in the cost of the finished product. There is no department in industry today that is more mysterious from a cost standpoint than that of heat treating. This has been caused by the fact that most industrial managers have only a very small idea of what heat treating really is and also by the fact that the science of metallurgy has developed so fast that the question of costs has been neglected.

One of the most important items in cost determination in the heat treating department is the proper distribution of the departmental burden on the various units of the department so that each one will bear its proper share. For the average heat treating department, the principal elements that constitute burden are fixed charges; which include the interest on investment in land, buildings, equipment and inventories, the real and personal property taxes, depreciation and repairs of buildings and equipment; indirect operating expenses such as supervision, indirect labor and

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A paper presented at the Indianapolis Convention. The author, Harold F. Wood, is chief metallurgist, Ingalls-Shepard Division, Wyman-Gordon Co., Harvey, Ill.

supplies (including coal and water) fuel or electric power, and miscellaneous manufacturing expenses such as employees liability insurance, etc.

The distribution of burden is brought about by the creation of various burden centers in the heat treating department. For instance, if a heat treating department is made up of four electric furnaces of the same construction and size, and 10 oil fired furnaces of the same construction and size, there would be two burden centers. However, if part of the furnaces are of different design and construction it is necessary to have more burden centers to enable accurate costs to be determined on each individual unit.

Interest—To determine the proper charge to each center for the use of equipment and in order to show the relation between the cost in centers equipped with expensive furnaces and those equipped with less expensive furnaces, interest at 5 per cent per annum on the investment in plant and inventory should be included as part of the burden. It might be said in passing that interest is an item that is neglected in many big companies today.

Taxes—State and county taxes on real and personal property should be included in the burden. Inasmuch as these taxes are levied on the assessed rather than appraised values, it is necessary to recalculate a rate based on appraised values in order to distribute this expense conveniently.

Depreciation and Repairs—The rates used in determining the amount of depreciation and repairs to be included in burden for cost purposes depends upon the design and construction of the particular furnaces making up the center in question. It has been the experience of the writer that a depreciation and repair rate of 10 per cent on well built electric and 15 per cent on well built oil furnaces is accurate. These rates depend to such a large extent on how the equipment is handled that it is impossible to estimate within plus or minus 2 per cent.

It is necessary to treat repairs as a fixed charge making the amount charged to cost on account of repairs uniform each month instead of showing a large fluctuation as would be the case if actual expenses were charged to cast as incurred. In connection with the depreciation and repair item the author desires to make the additional statement that a large number of companies that do keep accurate cost information make a mistake on the question of depreciation and repairs, because they consider by their experience that the repair rate over a period of time is so low that to charge off 15 per cent would be throwing too much of an extra burden on the furnace. They must take into consideration that with the strides that have been made in the past years in furnace design, the development of a furnace that is the last word today, is obsolete in about seven years. In other words, we must consider that a furnace must be either completely rebuilt or probably be completely replaced by a more modern furnace at the expiration of a period of seven years, so that would be about the maximum time that we should safely take in charging off the valuation of a furnace.

Land and Buildings Factor—The fixed charge on land is calculated by taking the sum of the interest and taxes of the land in question and dividing same by the land area in square feet. The fixed charge on buildings is calculated by taking the sum of the interest, taxes, depreciation and repairs on the building in question and dividing same by the building area in square feet. The rate on depreciation and repairs for heat

Form 270. 10M 4-4-21

FINISHING DIVISION

Clock No. 267
Part No. XM3029
Burden Center 42
Machine No. 6
Lab. No 342
Normalize °F
Harden 1525 °F
Draw °F
Shift Day
Signed ams
Approved F. G. M.

Normalize	Electric Furnace	Brinell	
Normalize-Str.	Straighten	Index	Weld
Harden ✓	Tong Ends	Lay Out	Pickle
Draw	Single Punch	Whiton Center	Regular Oper. ✓
Draw-Str.	Double Punch	Press Center	Extra Oper.

Quantity 35 Pcs. ~~Day~~ Piece Rate 2.00 Labor Amt. 70
Elapsed Time Hrs. Total Time Allowed Hrs. Bonus %
Occupation Hardener Burden Rate 1.00 Burden Amt.

Fig. 1—Productive labor ticket which shows the particular operation being performed and whether it is regular or extra

treating buildings depends upon their type of construction. For a well-built fire-proof building this rate is approximately 3 per cent. The fixed charge per square foot on land and buildings is the sum of the above two items.

The floor area of the entire heat treating department is distributed over the various burden centers in proportion to the exact area occupied by the various centers. The land and buildings factor for each burden center is the product of the fixed charge per square foot on land and buildings and the area in square feet of the particular center in question.

Equipment Factor—The fixed charge on equipment in a given center is determined by the product of the equipment valuation and the rates for interest, taxes, depreciation and repairs. The sum of these charges represents the total equipment factor.

Indirect Labor—Indirect labor in the heat treating department includes supervision, clerks, inspectors, truckers, janitors, timekeepers, allowances to piece workers, etc. The amount chargeable to burden is determined by estimate for a period of a year and distributed over the various burden centers of the heat treating department in a way that in the opinion of the superintendent is evenly divided.

Supplies—Certain materials are required in the operation of each center which do not enter directly into the products of that center. These include oil waste and grease, small tools, paint, water, coal, first aid supplies, disinfectants, electric power for lighting and operating cranes, but not for furnace heating, etc.

Power and Fuel—This covers the amount of fuel oil in the case of oil-fired furnaces or of electric power in the case of electric furnaces. The amount taken for each center is based upon the estimated tonnage to be treated and the hours to be worked for the year.

General Factory Burden—To be included in the cost chargeable to

each burden center is a certain percentage of the general factory burden. Just what this percentage will be cannot be determined without taking into consideration the size of the center in question together with the size of the entire factory and the importance of the center in relation to the factory as a whole. General factory burden includes all executive expense, office expenses including office help such as clerks, storekeepers, draftsmen, etc.

Miscellaneous Charges—Miscellaneous charges include all burden charges not covered by the previous headings. These consist principally of liability insurance, fixed charges on inventory, etc. The actual amount is usually determined each month and distributed to the proper burden centers.

Having determined the proper number of burden centers necessary for a particular heat treating department and developed the burden charges for each center, the next step is the determination of a proper furnace-hour rate for each center based on the total estimated furnace hours that will be realized in a year for the particular burden center in question. This rate is determined by dividing the total burden charge developed for each center by the total estimated furnace hours for each center.

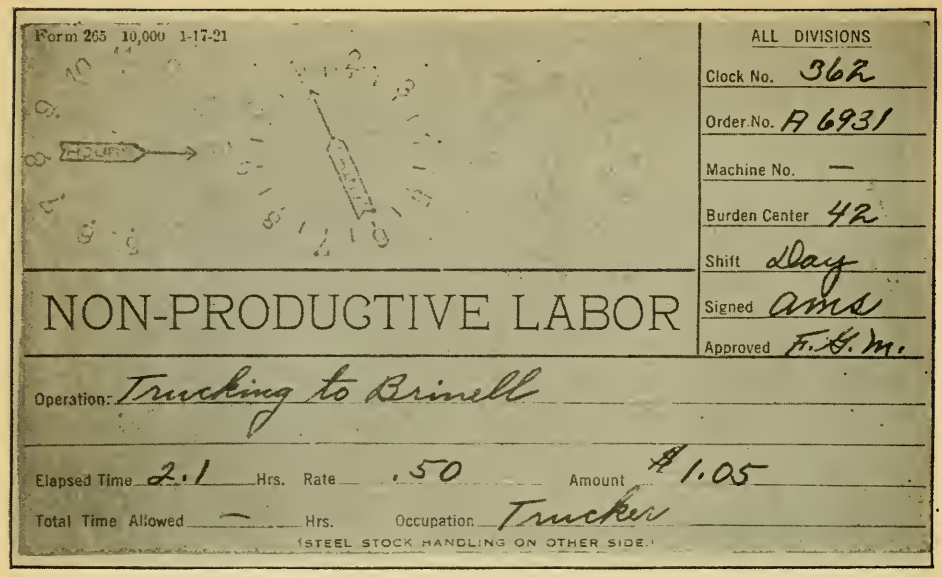
The accompanying table shows the development of a furnace hour rate for a burden center composed of six furnaces all of the same construction and size. The figures used are taken at random and merely show the detail analysis of how the furnace-hour rate is arrived at.

The determination of accurate costs can be brought about only by the use of an accurate system for the collection of all data that enters

Method of Determining a Furnace-Hour Rate

		Annual Amount
A—Land and Buildings Factor,		
1000 sq. ft. @ 30.00c per sq. ft.		$ 300.00
B—Equipment Factor,		
Furnaces (6)	$12,000.00	
Pyrometers	1,800.00	
Quench Tanks	400.00	
Monorail	200.00	
Hoist	600.00	
	$15,000.00	
Interest on $15,000 @ 5.0 per cent	$ 750.00	
Taxes on $15,000 @ .30 per cent	45.00	
Depreciation and Repairs on $15,000 @ 15 per cent	2,250.00	
	$3,045.00	
		3,045.00
C—Total Fixed Charges		$ 3,345.00
D—Indirect Labor		10,000.00
E—Supplies		1,500.00
F—Fuel oil (300,000 gal. @ 6c per gal.)		17,000.00
G—General Factory Burden (10.0 per cent)		3,500.00
H—Miscellaneous charges		655.00
I—Total Annual Burden		$36,000.00
J—Total estimated furnace hours—300 days per year, 20 hours per day, on six furnaces 300 x 20 x 6		36,000 hrs.

K—Furnace hour rate = $36,000.00 / 36,000 hr. = $1.00 per furnace hour.


Form 265 10,000 1-17-21

ALL DIVISIONS

Clock No. 362

Order No. A 6931

Machine No. —

Burden Center 42

Shift Day

Signed ams

Approved F. G. M.

NON-PRODUCTIVE LABOR

Operation: Trucking to Brinell

Elapsed Time 2.1 Hrs. Rate .50 Amount $1.05

Total Time Allowed — Hrs. Occupation Trucker

(STEEL STOCK HANDLING ON OTHER SIDE.)

Fig. 2—Nonproductive labor ticket covering all labor not pertaining directly to the actual heat treating operation

into costs. This is secured by the use of a job ticket system with accurate time clocks for measuring the exact elapsed time of each operation in hours and tenths of an hour. In the heat treating department it is possible to collect all data by the use of three kinds of job tickets, productive labor, nonproductive labor and lost time tickets. A detail description of each job ticket is given below.

In heat treating parts where they are put through in heats, one ticket is made out for each man of the crew and for each individual heat. In case parts are treated in continuous furnaces or as a continuous operation such as loading one piece and pulling one piece, one ticket for each member of crew is satisfactory as long as operation progresses in the regular way. The sample ticket shown in Fig. 2 shows in detail how each ticket is filled out. The particular operation being performed and whether this operation is regular or extra is checked. This enables the time office to collect all data for payroll purposes and the cost department to charge the cost to the proper account number. The productive labor ticket is used on all operations that enter into the actual heat treating of the part in question.

The nonproductive labor ticket, shown in Fig. 2, is used for all labor that does not pertain to the actual heat treating operation such as janitor work, clerks on hourly rate, truckers, etc. Many times it is best to give piece rates on nonproductive operations such as steel stock handling, etc. In this case the cost data is entered on the back side of the ticket as indicated in Fig. 3.

All lost time is collected and charged against the proper account number. This is an important item in the heat treating department. The heat treating superintendent never realizes the amount of lost time that exists in his department until each individual case is brought to his atten-

tion so that he can see the dollars and cents actual loss. A lost time ticket is shown in Fig. 4.

On many heat treating operations run on the piece work system, times occur when unforeseen difficulty is encountered that prevents the crew from making an amount which is equal to what they would have made had they been working day rate. If the difficulty encountered was not due to any neglect on the part of the crew, it is only fair that an allowance be made for the same. It will be noted that provision is made on this ticket for the approval of the division superintendent. This is important. In our plant we even go a step further on these particular

STEEL STOCK HANDLING

PART NO.	NO. PCS.	WEIGHT NET TONS	RATE	AMOUNT
XM3029	70	2.3	.07	.16
21428	300	15.0	.07	1.05
A6991	50	2.5	.07	.18
JE32	400	2.0	.07	.14
KL162	350	7.7	.05	.38
21689	360	11.5	.08	.92
K2186	110	10.0	.07	.70
XY71A	3000	50.0	.06	3.00
			TOTAL AMOUNT	$6.53

Fig. 3—Frequently it is desirable to give piece rates on nonproductive operations such as steel stock handling and these are entered on the back of the nonproductive labor ticket as shown

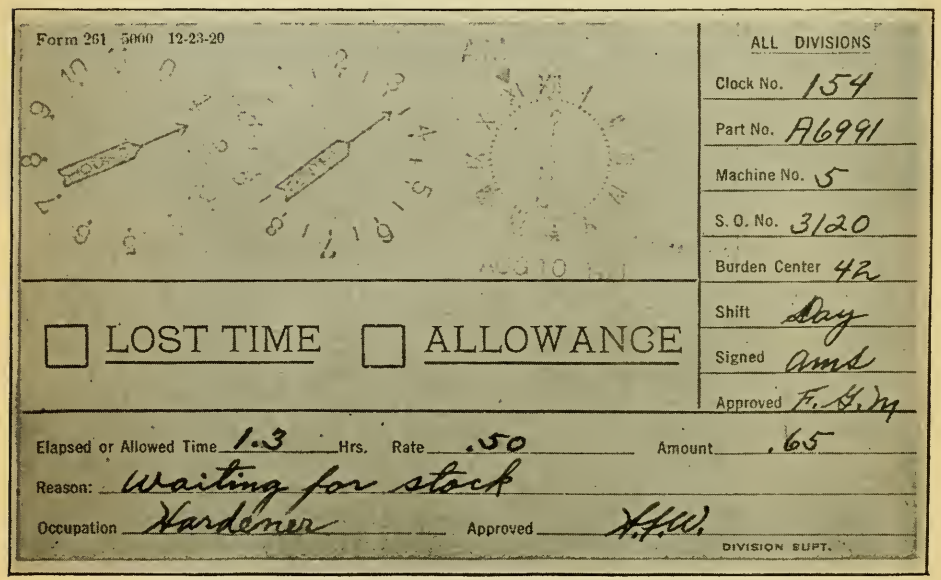
tickets and have them brought to the attention of the works manager before being urned over to the time office and cost department.

It is necessary in collecting cost data to make sure that every employe working either piece work or day work shall have a job ticket all the time. This makes it possible to divide the time accurately and see that same is charged properly by the cost department.

It will be noted that in the development of burden charges a large number of items are based on estimate. The cost as determined by using these burden charges, therefore, are not absolute costs. They are approximately accurate and for unit cost study in the plant, they are entirely satisfactory. However, for the preparation of actual profit and loss state-

ments for each month, it is necessary to go further. The balances remaining in the various burden accounts after credit has been entered for earned burden are transferred to the unearned burden and burden variance account at the close of each month. A debit balance will represent a loss due to unused heat treating capacity or an increase in the actual burden charges over the estimate or standard. Statements showing detail analysis of this account are prepared monthly.

It is impossible to overestimate the effect of proper cost analysis on the heat treating department. It has been general policy for years to keep costs away from the shop foreman and superintendents. The heat treating superintendent of today must be able to think in terms of dollars and cents. The only way he can be educated to do this is to secure from the cost department full information on the costs of each operation in his


Form 261 5000 12-23-20

ALL DIVISIONS

Clock No. 154

Part No. A6991

Machine No. 5

S. O. No. 3120

Burden Center 42

Shift Day

Signed Ams

Approved F. H. M

☐ LOST TIME ☐ ALLOWANCE

Elapsed or Allowed Time 1.3 Hrs. Rate .50 Amount .65

Reason: Waiting for stock

Occupation Hardener Approved H.F.W.

DIVISION SUPT.

Fig. 4—Lost time and allowance ticket showing how lost time is charged against each account. This is an important item

department in statements issued by the cost department at least once per month. These statements should show the unit cost on each operation on each job run, detail analysis of all lost time showing dollars and cents actual loss and subdivided into causes, and a detail analysis of all extra operations performed placing definite responsibility for same.

A study of these monthly reports enables the heat treating superintendent to definitely locate where the losses occur so he can take immediate steps to reduce them to a minimum. A comparison of these statements with those for the month before will show at a glance actual progress made in reducing heat treating costs.

From these statements it is possible to prepare unit costs per piece or per pound on the different jobs and for each individual operation on a given job. All pieces rejected in the heat treating department should be taken to a definite location daily. The first thing each morning a conference should be held and each piece gone over carefully. At this con-

ference the dollars and cents actual loss to the company should be brought out and impressed upon the foremen as well as the men actually causing the rejection. If this study is carried out carefully on the part of every one concerned, the heat treating superintendent will find that his costs can be lowered materially and his production efficiency greatly increased.

MR. PORTER: I wanted to ask the speaker about the size of the plant in which he uses this system, the number of men involved and how easily the data is collected. I studied that thing in machine work. It was just the same principle. I found it extremely difficult to get that data together myself.

Discussion of Mr. Wood's Paper

MR. WOOD: In our shop when we are running normal, we have about 750 men working, and it is necessary to have two production clerks in the shop to gather the data. In addition to that we have two men in the cost department which prepare all the cards. The reason we are able to do that is because of the simplicity of the cards themselves.

One question that has already been raised, going into a detailed cost discussion is that each company always has its own particular cost method, which it has worked up through a number of years, and this company finds that this is particularly adapted to its particular work. We don't recommend that they change their cost system, but all we do want to do is to impress the importance of the different individual units, to make sure they are included. You would be surprised to find out how many companies neglect a lot of the important items. In the drop forge industry, it is even more pronounced than in the straight heat treating.

MR. PORTER: Do you use a tabulating machine?

MR. WOOD: We don't at the present time, although it is a simple matter to punch holes in the cards and use a sorting and tabulating machine.

CHAIRMAN HARTZELL: This is an extremely interesting topic. I believe that the report submitted by the Commission of Engineers, who investigated about three hundred steel farbicating plants in the country on the matter of time, material, and man waste, arrived at some such conclusions as these.

Only ten per cent of the three hundred plants in this country knew which it cost them to waste man power. About fifty per cent of the three hundred had no system whatsoever for determining cost. Thirty-five per cent did not make more than $5,000 profit. That was startling.

Yesterday I was talking with the representative of a consulting engineering firm along these lines, and he said that actually, while things were going so well, he thought his company was making money. Then when the slump came and he began studying his own company he found that they were not making money, but were actually losing money. That is to say, money was coming in so fast and it went out so fast they thought go into another concern and show that concern where they were losing they were making money when actually they were losing it, yet he could money. He said it was a startling revelation.

HEAT TREATMENT OF CHROME STEEL FOR BALL BEARINGS

By Haakon Styri

HIGHEST grade steel for ball bearings contains about 1.0 per cent carbon and 1.4 per cent chromium and, therefore, must be heat treated with the greatest care to give the best results, both during manufacturing and as the finished product.

Some of the material is delivered to the plants in a hot rolled condition, with a microstructure of lamellar pearlite and cementite boundaries when it is to be used for forgings of balls or ball races. A specimen of this is shown in Fig. 1. However, most material is delivered in the annealed condition for the automatic machines and must have a structure consisting of fine granular pearlite, as shown in Fig. 2. If the structure contains any lamellar pearlite the Brinell hardness generally will be higher and the cutting tools will be dulled quicker. Figs. 2, 3 and 4 show structures with Brinell hardness respectively 180, 203 and 236. Occasionally we find annealed bars which are hard in spots where the temperature has been too high during annealing and has caused more or less lamellar pearlite to be formed, as shown in Fig. 5. Such material, as well as material with seams, Fig. 6, and carbide segregations and slags, Fig. 7, is rejected.

Before the material is subjected to hardening it must have a structure of granular pearlite. All forged material is therefore annealed before hardening. A careful hardening is of the greatest importance for the quality of the product, and it is first of all necessary that the steel be in homogeneous condition when it is ready to be quenched from the proper temperature. It is not enough that the steel has reached such temperature, but sufficient soaking must be allowed, in particular for chromium steels, which react slower than carbon steels.

Some experiments the author made on carbon steels some years ago will illustrate the effect of insufficient soaking. Carbon steels of 0.30, 0.50 and 0.80 per cent carbon content were heated rapidly in a hot furnace to just over the critical temperature and left only 5 minutes before they were cooled off slowly. Figs. 8 and 9 show that the transformation into pearlite or sorbite has started only in points, and parts of the material are retained as ferrite or divorced pearlite as in the original condition. If the material is quenched after such short time of heating, as shown in Figs. 10, 11 and 12, we find similarly that only a part has gone into solid solution and forms martensite, which often is not homogeneous as shown by Fig. 11. We get a similar condition in chrome steels when the temperature is too low or the time for soaking is insufficient as shown in Fig. 13.

When the steel has not been in the proper condition before hardening we can get martensite with streaks of cementite, Fig. 15, or with cementite boundaries, Fig. 14. Properly heat-treated steel will show fine martensite with granular cementite, Fig. 16. Overheating gives coarse martensite, Fig. 17 and, if exaggerated, even some austenite, Fig. 18.

Several interesting abnormalities have been found in hardening, which will be described later, as it may be of value first briefly to consider hard-

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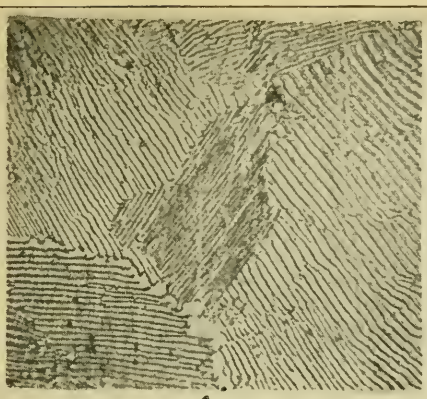
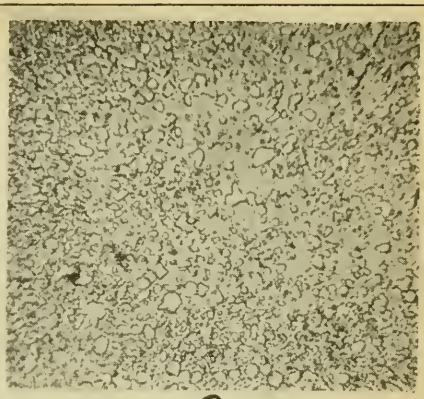
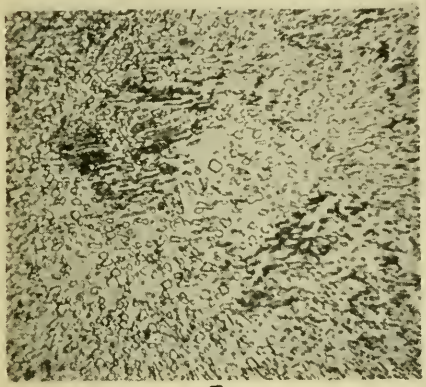
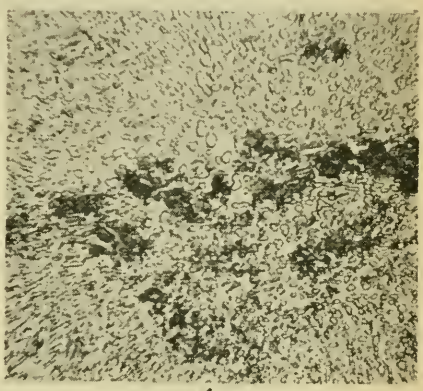
A paper presented by title at the Indianapolis Convention. The author, Haakon Styri, is chief of the SKF research laboratory, SKF Industries, Philadelphia.









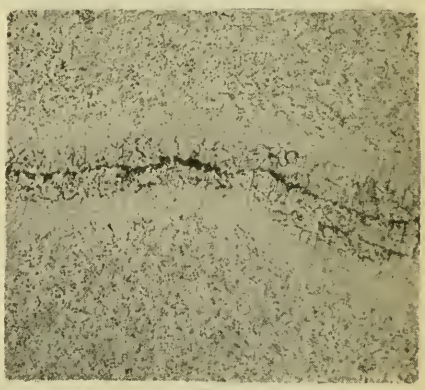
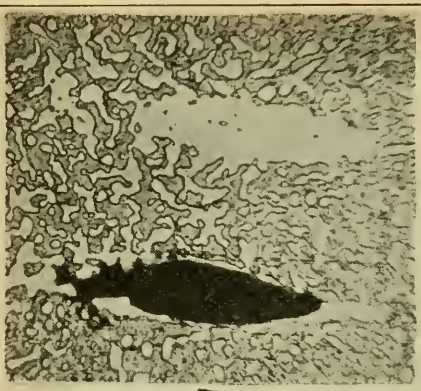


Fig. 1—Lamellar pearlite. Brinell 217. X 1000. Fig. 2—Granular pearlite. Brinell 180. X 1000. Fig. 3—Granular pearlite with a little lamellar pearlite. Brinell 203. X 1000. Fig. 4—Granular pearlite with considerable sorbitic pearlite. Brinell 236. X 1000. Fig. 5—Sorbitic and lamellar pearlite with cementite boundaries. Brinell 305. X 1000. Fig. 6—Surface seam from hot rolled bar stock, not rough turned. X 1000



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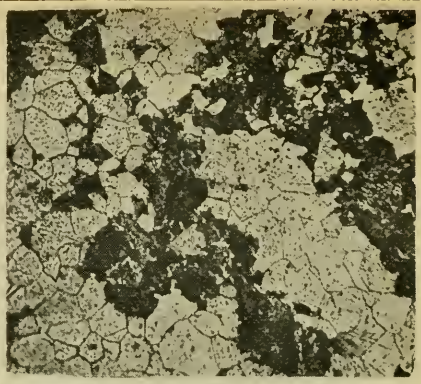

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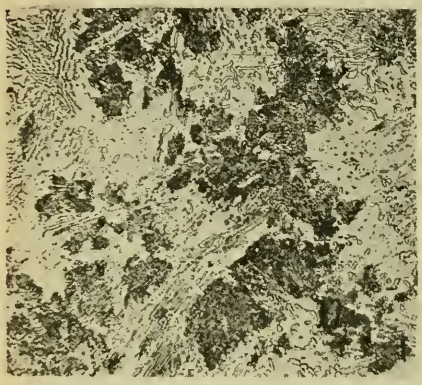

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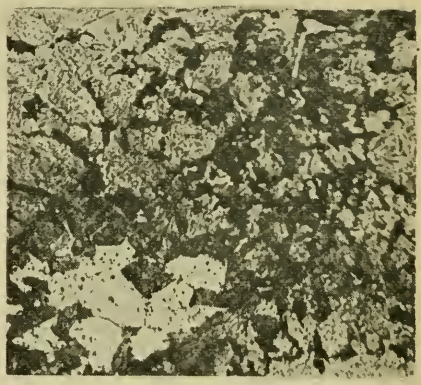

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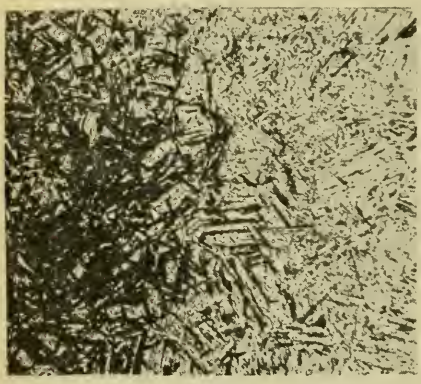

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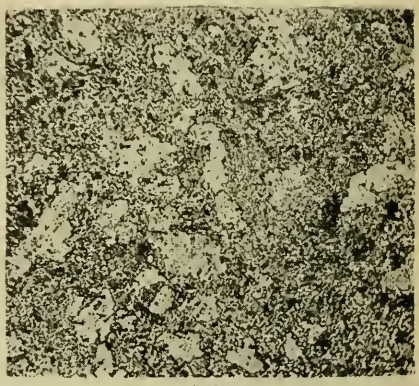

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Fig. 7—Martensitic structure with carbide and slag. X 1000. Fig. 8—Steel of 0.30 per cent carbon heated to 720 degrees Cent. for 5 minutes and furnace cooled. X 250. Fig. 9—Steel of 0.50 per cent carbon heated to 720 degrees Cent. for 5 minutes and furnace cooled. X 250. Fig. 10—Steel of 0.30 per cent carbon quenched in water from 720 degrees Cent. X 250. Fig. 11—Steel of 0.30 per cent carbon quenched in water from 900 degrees Cent. X 250. Fig. 12—Steel of 0.80 per cent carbon quenched in water from 720 degrees Cent. X 250

ening in general. It is not the intention to elaborate on this, as the author two years ago gave a paper on this subject before the Pittsburgh Chapter of this Society, in which he tried to give an outline of the most important facts known about hardening of steel, and which would form a satisfactory basis for a clear theory of hardening. It may be sufficient only to mention the most important of these facts, namely, the simultaneous contraction, heat absorption and loss in magnetism on heating through the critical range and the reverse process at slightly lower temperature on slow cooling. When steel cooled rapidly, such changes do not occur at the same temperatures, but take place more or less marked at lower temperatures, as it is very clearly shown in the recent investigation of Portevin & Garvin[1].

On investigating the influence of rate of cooling on the hardening of carbon steels, they established without doubt that the formation of troostite occurs through a temperature range above 600 degrees Cent. with evolution of heat and is prevented only by sufficiently rapid cooling through that range, or critical rate of quenching. They also showed that if the cooling is rapid enough to prevent the formation of troostite with its corresponding heat evolution, another heat evolution may take place below 350 degrees Cent. and the structure of steel showing this phenomenon will be martensitic. The transformation of solid solution into martensite, in other words, has taken place below 350 degrees Cent. This transformation is slow relative to the rapid troostite formation at the higher temperatures. With an accelerated rate of cooling the troostite formation gradually gets weaker until, at the critical rate of quenching, it disappears and the martensite transformation only takes place. Both troostite and martensite can be found in the same specimens with quenching rate near this critical rate, and are found simultaneously even in special steels which have much lower critical rate of quenching.

The critical rate of quenching under otherwise similar conditions is least near the eutectoid composition—which means that when the steel has more carbon or less carbon than 0.9 per cent, it is necessary to have more rapid cooling in order to prevent troostite formation. If cooled more rapidly through the range above 600 degrees Cent., but with cooling interrupted at lower temperature, troostite can be formed at the lower temperature of 400 to 450 degrees Cent.

The initial state of the steel is of considerable importance, as shown by the effect of increase in quenching temperature. This is shown by Portevin but can, to a large extent, be explained by cooling curves calculated by K. Heindlhofer of the S. K. F. laboratory. His calculations were undertaken in order to get a general idea of the cooling of different points in a sample under given conditions. These were assumed to be as follows:

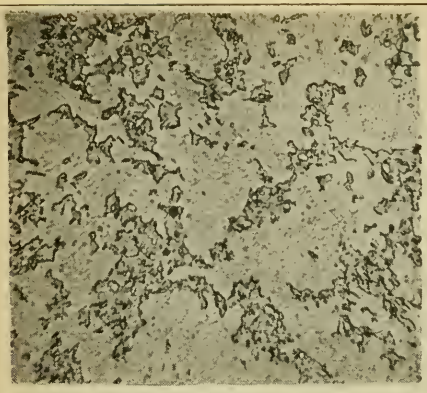
Steel ball of given dimension, 1 centimeter radius.

Heat conductivity of steel, 1 gram calorie per centimeter per second.

Specific heat of steel, 0.114.

The cooling was supposed to take place in a liquid which was constantly renewed so that it kept its temperature constant, and there was supposed to be no contact resistance between the ball and liquid. Cooling curves, temperature and time were calculated for points at equal inter-

1. Portevin and Garvin Journal Iron and Steel Institute, 1919.



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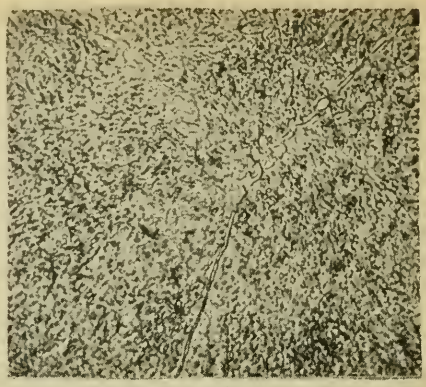

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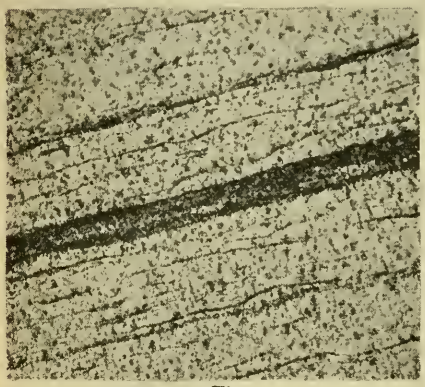

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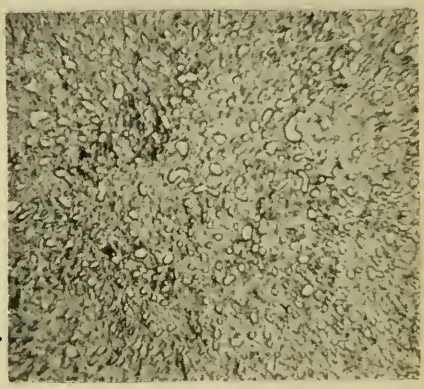

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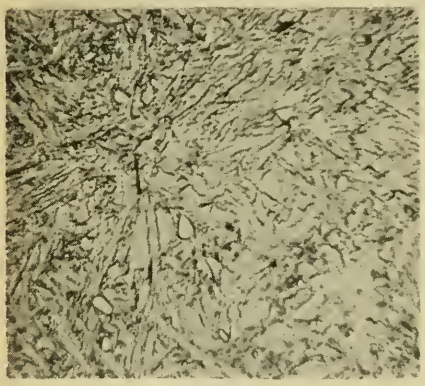

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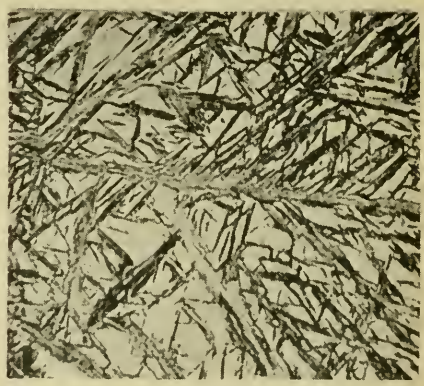

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Fig. 13—Undissolved granular pearlite in martensite lightly etched. X 500. Fig. 14—Martensitic structure with network of interrupted cementite boundries. X 1000. Fig. 15—Very streaky structure showing cementite streakiness. X 50. Fig. 16—Good hardened structure in ball bearing steel. X 1000. Fig. 17—Very coarse martensitic structure due to overheating. X 1000. Fig. 18—Ball bearing steel quenched from 1900 degrees Fahr. in oil and drawn to 400 degrees Fahr. showing coarse martensite in an austenitic ground mass. X 500.

vals of 1/10 of the radius. The result of the calculation may be summarized as shown in Fig. 19.

The temperature ordinate at zero time represents the initial temperature difference between the ball and the liquid, and can be expressed in per cent, representing any initial temperature chosen. For any temperature we can therefore use the percentage scale and the cooling curves will have the same form. For a variation in diameter of the ball there is a simple

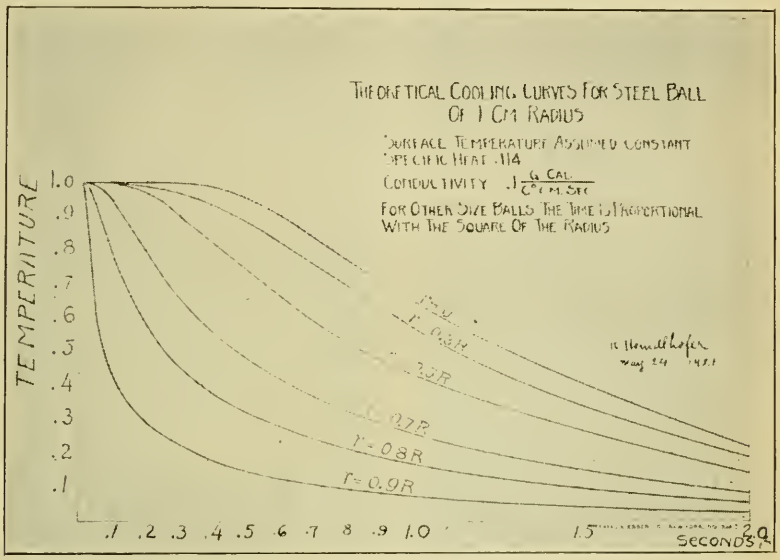


Fig. 19—Theoretical cooling curves for steel ball 1 centimeter in radius. By Heindlhofer

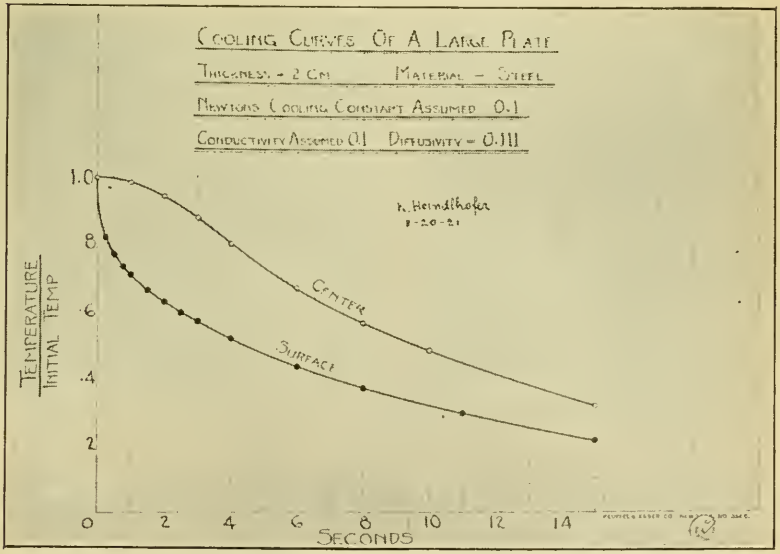


Fig. 20—Cooling curves for a large plate of 2 centimeter thickness. By Heindlhofer

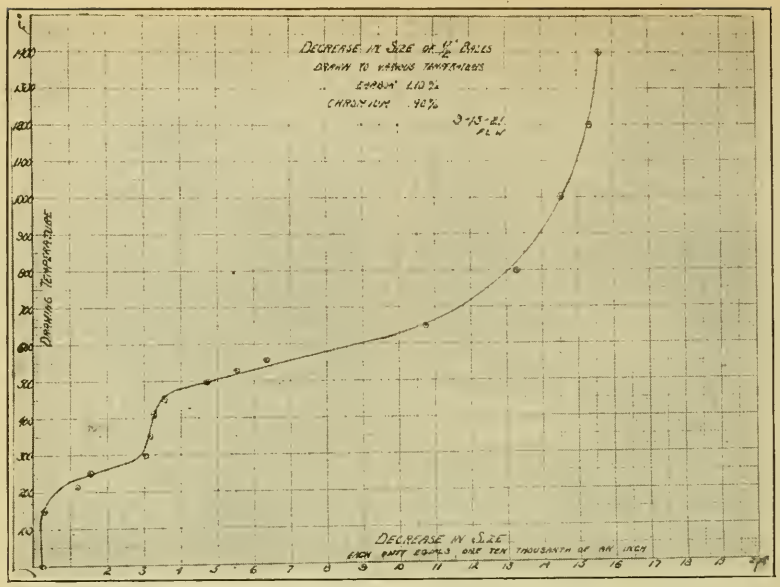
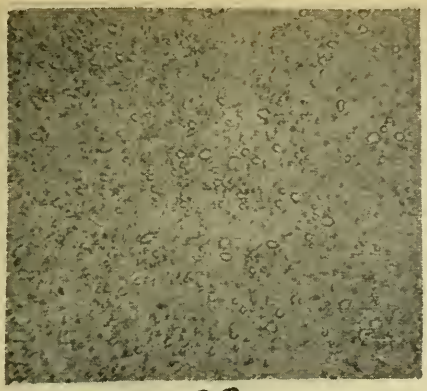


Fig. 21—Change in size of balls due to drawing to different temperatures. By Wright

relation in cooling time which will increase with the square of the diameter. In other words, if the scale used for dimensions is changed from, for instance, 1 square = 1 centimeter to 1 square = 2 centimeters the figures given for time must be multiplied by 4 and the same curves can be used.

The whole system is readily understood when made up in a wooden model. To illustrate the use of such a model let us see what happens in the different points when the ball is quenched from 750 degrees Cent. and we assume that for a given steel the critical rate of quenching through the range of troostite formation, near 600 degrees Cent., is about 100 degrees per second. Where the temperature drop through this range is less rapid, troostite should result. This can occur for the center of the ball. But if we raise the initial quenching temperature, the corresponding cooling curve will show a more rapid drop and we will get no troostite at this point.

If the heat conductivity in the steel decreases, the corresponding time will increase with the 2nd power. If the cooling liquid is changed, the result can be imagined by stating that for a given liquid the layer next to the ball will be maintained at a constant temperature, and we can again use our curve representing the total temperature in percentage. But if a layer of a different nature is formed at the contact surface, for instance, a layer of steam is formed when water is used as a quenching medium, or if scale is present on the surface, we can regard such a layer as an insulating material with a certain resistance against heat transfer. The cooling curves will fall at a slower rate and there will not be so great a difference between the rate of cooling for the surface and the center of the ball. The better the insulation, the less difference there will be in the rate of cooling. Mr. Heindlhofer has calculated the cooling curves



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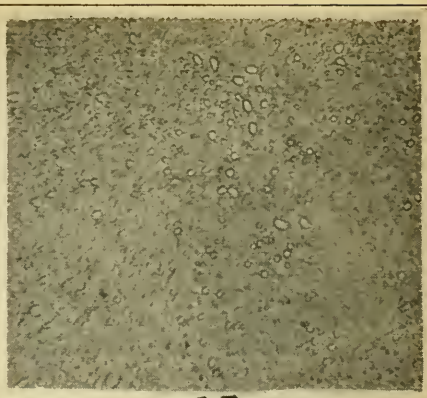

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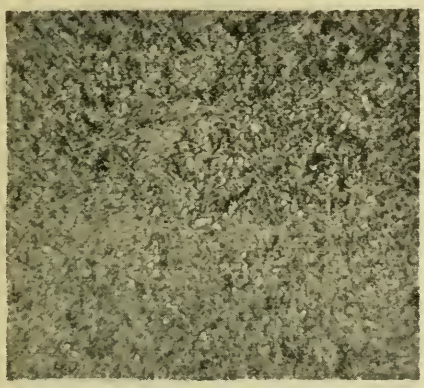

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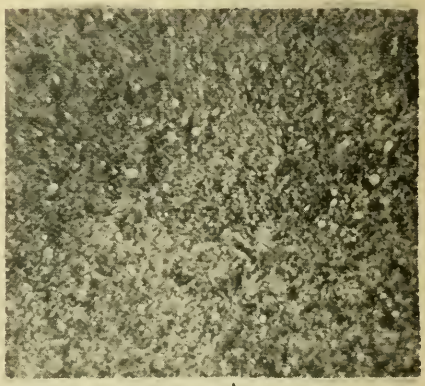

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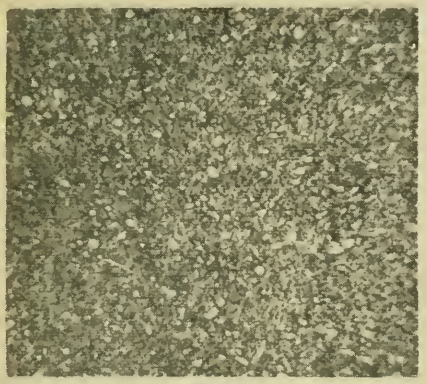

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Fig. 22—Ball of ½-inch diameter, hardened but not drawn. X 1000. Fig. 23—Ball of ½-inch diameter, hardened and drawn 30 minutes at 255 degrees Fahr. X 1000. Fig. 24—Ball of ½-inch diameter, hardened and drawn 30 minutes at 450 degrees Fahr. X 1000. Fig. 25—Ball of ½-inch diameter, hardened and drawn 30 minutes at 500 degrees Fahr. X 1000. Fig. 26—Ball of ½-inch diameter, hardened and drawn 30 minutes at 675 degrees Fahr. X 1000. Fig. 27—Ball of ½-inch diameter, hardened and drawn 30 minutes at 924 degrees Fahr. X 1000

for the surface and the center of a big plate under the assumption of a surface insulation as indicated in Fig. 20.

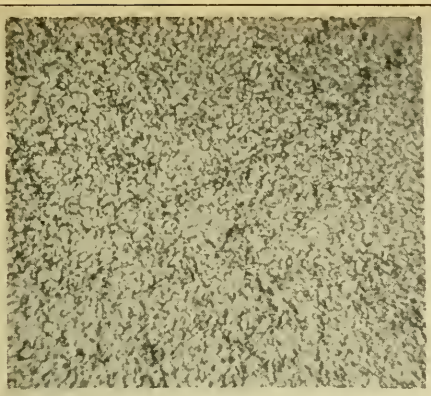
However, it is not only an increase of initial temperature shown that may account for a change in structure. The higher temperature to which the steel has been heated may have caused a structural change so that only a slower rate of cooling is necessary in order to suppress the troostite formation. The investigation of Andrew Rippon Mills[2] throws light on this question. The excellent curves given for the expansion on heating of steels of different carbon contents show, in addition to the known contraction on changing from alpha to gamma iron, that there is an expansion of gamma due to solution of cementite. This expansion is not completed at Acm when cementite has disappeared in the microstructure, but continues until considerably higher temperature is reached. They seem to attribute the known increase in volume of a hardened steel over the annealed to this cementite expansion.

The larger volume of martensitic steels can hardly be explained by this only. It seems to the author that part of such expansion at least can be accounted for by minute slippage in grains when gamma changes to alpha iron. Some experiments on change of dimension by drawing hardened balls which we have made, may be of interest in this connection. These measurements are shown in the curves in Fig. 21.

Undoubtedly there is a decrease in volume when a hardened specimen is drawn to higher temperatures, and this is accompanied by some separation of cementite from solution and a coagulation which, as the pictures show, is very evident at 400 degrees Cent. Fig. 22 was not drawn; Fig. 23 was drawn at 120 degrees Cent.; 24 was drawn at 230 degrees Cent.; 25 was drawn at 260 degrees Cent.; 26 was drawn at 355 degrees Cent.; 27 was drawn at 495 degrees Cent.; 28 was drawn at 650 degrees Cent. However, the contraction seems to continue after the cementite is separated out.

We will now describe some of the abnormalities in the quenching referred to above. The martensite formation is, as mentioned, found to take place below 350 degrees Cent. If the rate of cooling is fast enough this may be depressed and we get austenite. The formation of martensite, however, is not sudden. It takes time to complete it. Therefore, it may well happen that a change can occur, when for some reason the cooling is interrupted. At such time there will be a gradual fall in temperature from the center to the surface of the specimen. Let us imagine that we cool off a ball rapidly until the surface temperature has fallen below the temperature for martensite formation, 350 degrees Cent., and that the cooling be interrupted for a moment by a local steam pocket. The heat from the interior will then raise the temperature of the spot when some martensite has formed and draw this back to troostite. At this time the steam pocket may disappear and the normal rate of cooling be resumed so that the originally unchanged solid solution will change into martensite. Such process may result in what we have called surface troostite, which we have often found on hardened balls, as shown in Fig. 29. We have found similar formations in a block of straight carbon steel quenched according to the hump method. Near the surface a decarbonized layer is found, then a layer of surface troostite, as shown in Fig. 30, then one of martensite, as shown in Fig. 31, then one of ordinary

2. Andrew Rippon Mills, Journal Iron and Steel Institute, 1920.



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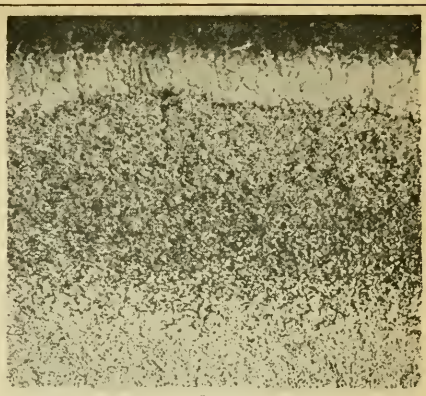

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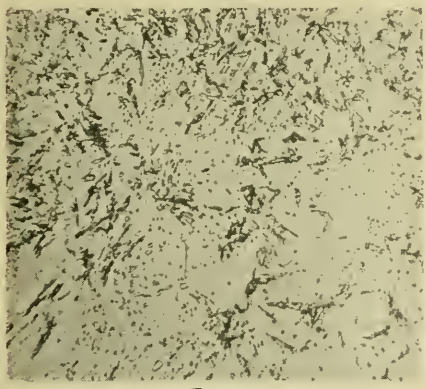

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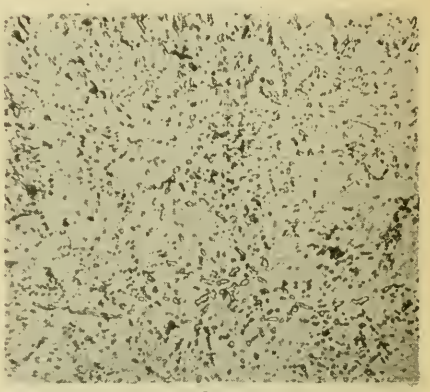

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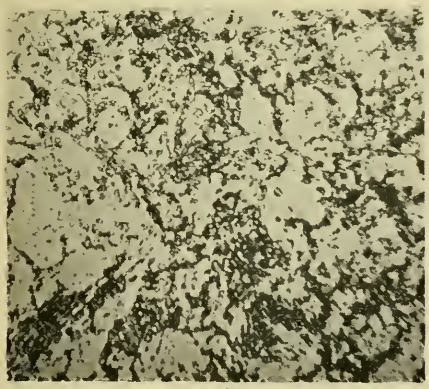

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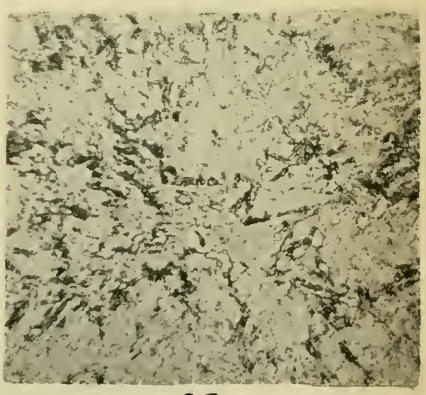

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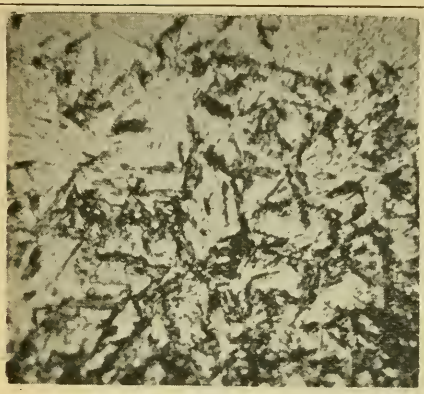
Fig. 28—Ball of ½-inch diameter, hardened and drawn 30 minutes at 1200 degrees Fahr. X 1000. Fig. 29—Surface troostite with some decarbonization. Hump method used. X 100. Fig. 30—Straight carbon tool steel hardened by hump method, showing surface troostite. X 500. Fig. 31—Specimen showing martensite beneath surface troostite. X 500. Fig. 32—Same as Fig. 30, showing troostite beneath the ⅛-inch layer of martensite. X 500. Fig. 33—Surface troostite in martensite. X 1000



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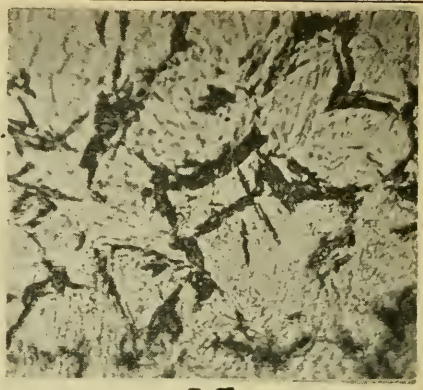

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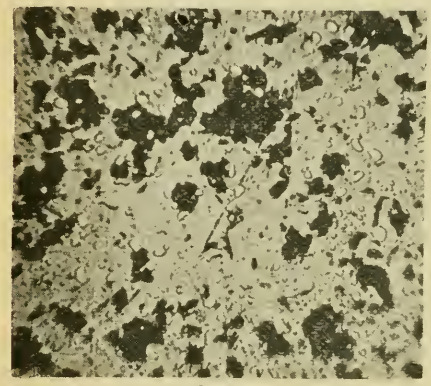

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Fig. 34—Surface troostite with some decarbonization. X 1000. Fig. 35—Surface troostite in martensite. X 1000. Fig. 36—Surface troostite in martensite. X 1000. Fig. 37—Surface troostite in martensite. X 1000. Fig. 38—Secondary ferrite in martensite. X 1000

quenching troostite, as shown in Fig. 32. It is well to notice here that such troostite mixed with martensite is produced in quenching and not in drawing. The drawing troostite is homogeneous throughout, as shown in Figs. 24 and 25.

The surface troostite generally has a form entirely different from troostite formed in steel by slow cooling through the range around 600 degrees Cent. Figs. 33, 34 and 35 show forms of troostite found on steel balls in the shape of needles more or less drawn, but there are forms, shown in Figs. 36 and 37, also from surfaces which are much like troostite formed in the interior when too slowly cooled through the critical range. Mr. Hultgren, of Sweden, has in particular called attention to these various forms of troostite. A further abnormality is what Mr. Hultgren has called secondary ferrite, as shown in Fig. 38, on which he has thrown some light in his investigation of tungsten steels where he shows the formation to start on retarded cooling in the temperature range between 600 to 525 degrees Cent. and to be maximum around 500 degrees Cent.

In conclusion the author wants to emphasize the necessity of thorough soaking at temperature before quenching and a regulation of the quenching temperature to correspond to size of specimen and system of quenching. He also wants to point out the importance of recognizing the different forms of troostite, in particular the difference between troostite formed during the quenching period and troostite formed by the drawing of martensite. The latter troostite is homogeneous, the former is found in conjunction with martensite, or sorbite, and is not entirely homogeneous when it happens to occur alone.

Discussion of Mr. Styri's Paper

CHAIRMAN HARDER: Have you observed in any case an increase in volume instead of a decrease in any of the drawing operations?

MR. STYRI: Yes, we have, but not for this kind of steel. For another type of steel we have found an increase in volume at about 450 degrees Fahr. For that kind of steel we had the curve coming up this way. That is to say, first a decrease in size, and then an increase in size, for a higher drawing temperature. That can be explained only by the transformation of gamma iron. It is an increase in volume from austenite to martensite. This question belongs to another investigation and it would take considerable time to go into that.

CHAIRMAN HARDER: Would you consider it possible that the decrease in volume in the second part of that curve might be due to the decrease in volume of a precipitated cementite, due to the growth of cementite particles during the drawing operation?

MR. STYRI: I don't think so because a single coagulation of cementite should not cause a decrease in volume. On the other hand, we know that cold worked steel has a larger volume than unworked and will contract on being drawn to higher temperatures due to closing up of slips.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

HIGH SPEED STEEL PAPER IS CORRECTED

THROUGH an unfortunate set of circumstances, three errors appeared in the paper "Physical Tests on High Speed Steels," by A. H. d'Arcambal, which appeared on page 586 of the April issue of TRANSACTIONS. To clear up any question which may have been caused by these inaccuracies, the corrections are given below.

In the sentence, "Drawing to 1100 degrees Fahr. into oil or lead," etc., which begins in the ninth line on page 591, a number of words which appeared in the author's manuscript were dropped out with the result that the sentence is meaningless. With the missing words supplied, the sentence should read "Drawing to 1100 degrees Fahr. produced a small amount of troostite with its corresponding softness. Specimens of both types of steel quenched from 2350 degrees Fahr. into oil or lead and not drawn possessed the polyhedral structure of austenite with only a few undissolved carbides and tungstides."

In the small insert at the bottom of page 591, the chromium content should have been shown as 3.31 per cent instead of 3.13 per cent as was printed. On page 593 in the eighteenth line from the top of the page, Figs. 25-30 should have been referred to instead of Figs. 18-24.

Mr. d'Arcambal also calls attention to the fact that on page 567, the fifteenth line should have referred to a 14.0 per cent chromium steel instead of a 0.40 per cent chromium steel as shown.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. *What is needle bar stock?*

QUESTION NO. 6. *Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?*

QUESTION NO. 7. *May tools be heat treated properly in a furnace in which copper is present?*

QUESTION NO. 8. *What is the effect of high and low silicon in tool steel?*

QUESTION NO. 9. *In carbonizing does not the carbon increase slightly even in the core section?*

QUESTION NO. 10. *What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?*

QUESTION NO. 11. *Has high speed steel ever been carbonized and if so what were the results?*

QUESTION NO. 12. *How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?*

QUESTION NO. 13. *A swaging die for tubing receives* 3600 *blows per minute. It has been found that a scleroscope hardness of about* 95 *is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?*

QUESTION NO. 14. *What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.*

QUESTION NO. 20. *What are the causes of warping in the heating and cooling of steel?*

ANSWER. By Stanley A. Richardson, instructor in metallurgy, Lewis Institute, Chicago.

The warping of steel has been a problem to steel treaters, it may be said, since steel treating began. With the increasing use of heat treated structural parts, particularly those of considerable length or cross section, the problem has increased in importance. It is held quite generally among shopmen that warping is in some way the result of nonuniform heating or cooling. Cracking, during or subsequent to heat treating, is thought to be due largely to the same thing. That is to say, warping and cracking are phenomena of like kind, differing only in degree. It is probably correct to say that the majority of technical men attribute these phenomena to the volume changes associated with the passage of a piece of steel through critical temperatures.

It is evident that the aforementioned views are not antagonistic, but are substantially in agreement. If a volume change causes a piece of steel to warp or crack, it must be because there is an interval between the time of the change in various parts of the piece, and this of course means that the rate of cooling, or heating, is not uniform. It is undoubtedly true, however, that there are many heat treaters who overlook the fact that a piece of steel undergoes a sudden expansion while cooling through the critical temperature, or, the reverse on heating.

In addition to the above, it is sometimes held that warping is due to a mechanical action, wherein the section of the steel cooled at the more rapid rate "upsets" the section cooling, at the slower rate. In view of the fact that in a piece of steel, one side of which is quenched in water, the quenched side is found to be longer than the side cooling in air, it is not clear to the writer just how this "upsetting" can take place. It is conceivable, and a matter of fairly common observation that steel can be warped by uneven heating before reaching the critical temperature. Such a condition is due, evidently, to the fact that because of differences in the rate of expansion of adjoining sections, stresses are set up which exceed the elastic limit of the steel and thereby produce distortion. Assuming homogeneous material, proper furnace design and proper furnace loading, should greatly reduce, if not eliminate this condition. Warping of this nature is probably more noticeable in the case of pieces of great length or uneven cross section. The tendency of steel to warp or crack under this condition is said to vary inversely with its thermal conductivity and directly with its coefficient of expansion. It is more pronounced, of course, in some steels than in others, probably reaching a maximum in high manganese steel, which can be cracked very easily by uneven heating.

The writer has listened to much discussion by practical men at recent meetings of the Chicago Chapter relative to the foregoing. However, after examining a number of the specimens presented, he is of the opinion that the real mechanism of warping in steels quenched from above the critical range, in the vast majority of instances at least, hinges upon the formation in the steel of varying amounts of the constituents marking the transition from austenite to pearlite, for example, martensite, troostite, and sorbite.

It is a matter of common knowledge among metallurgists that each of the metallographic constituents of steel possesses a different specific volume or density. Quantitative determinations confirming this have been made by various authorities, notably Maurer and other prominent European metallurgists and physicists. Martensite, the constituent produced by quenching a piece of properly heated steel in water, has a greater specific volume than any of the other constituents. In a piece of steel, the greater dimension of which is length, this is equal to saying that the piece will be longer after

quenching than before. Troostite and sorbite each have a specific volume somewhat less than that of martensite. When martensite and troostite, or troosto-sorbite are formed in quantity in a piece of steel, the ideal condition for distortion exists. The effect increases with increase in the carbon content, which means of course that the effect depends upon the total amount of martensite and troosto-sorbite present. A piece of low carbon steel containing these constituents will undergo a slight deformation, whereas in a high carbon steel the deformation will be quite pronounced, or, in most cases due to its low ductility, the steel will crack. The cracks are usually parallel to, and close to the line dividing the martensite from the troostite, and appear to be due to the tension placed on the martensitic area by the contraction accompanying the formation of troostite. Frequently in a high carbon steel, cracks appear also in the martensitic area in a direction at right angles to the previously mentioned dividing line. The tendency to crack is influenced profoundly of course, by the degree of temperature to which the steel is heated above the critical point, being greater in steel highly overheated. That is to say, coarse grained martensite is more brittle than that of normal grain size. The production of concentrated areas of martensite and troostite in a piece of steel may be caused by uneven quenching or cooling of the piece, unequal temperature throughout at time of quenching, unequal drawing or tempering, and probably, nonuniform distribution, or concentration of the elements, particularly carbon. The last mentioned condition can usually be corrected by a thorough anneal, while the others depend upon factors peculiar to any individual plant.

The following simple experiments, performed in studying this problem, are interesting, and can be duplicated in any shop. They were carried out under shop conditions without attempt to exact quantitative data. The changes in dimension were measured chiefly by tracing the outlines of the pieces on paper before and after the heat treating operations. Pieces of 0.20 per cent carbon, 0.50 per cent carbon, and 0.90 per cent carbon steel, each about 6 by 3 by 3/8 inches were heated to their respective proper quenching temperature and quenched about one-half of their width, that is about 1 1/2 inches in cold water, and the microconstituents noted. In addition, pieces of 0.50 per cent and 0.90 per cent carbon steel were heated and quenched uniformly, and then immersed for about one-half their width in cold running water and a drawing temperature applied to the upper edges with an acetylene torch. This temperature probably reached 900 degrees Fahr. at the upper edge of the pieces and graduated downward to the surface of the water. The results obtained including the cracking were almost identical with those obtained by quenching but one-half of the specimens in water and not tempering.

In the case of 0.20 per cent carbon steel it is necessary to quench the piece at least twice in exactly the same manner to produce a very marked deformation. This is to be expected when it is considered that steel of this carbon content can possess but 24 per cent of saturated martensite. As the stresses set up by each quenching exceed the elastic limit of the steel, the effect, that is the distortion, is cumulative. If the piece is very wide a bulge will be noticed on the ends of the section farthest from the surface of the water, for example, the section cooling at the slowest rate. This bulge will have a greater length than the troosto-sorbitic area, but less than the quenched or martensitic area. Upon examination it will be found to consist of lamellar pearlite.

The foregoing observations and experiments are not offered as being conclusive. It is believed, however, that they point toward an answer to a practical question—which answer the writer, at least has never seen or heard discussed. It would appear, then, that a very large part of the warping and cracking of quenched steels, while possibly due to uneven temperature conditions, is not due necessarily to unequal thermal expansion or contraction, but to the formation in the steel of transition constituents having different specific volumes.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

EFFECT OF COLD DRAWING

TENSILE STRENGTH INCREASE BY COLD DRAWING. By E. J. Janitzky, *Iron Age*, Vol. 109, Page 707.

Considerable data has been published on the influence of cold drawing on tensile strength, but no mathematical analysis has been made of it. On 0.10 per cent carbon steels the increase in tensile strength is equal to one thousand times the per cent reduction of area up to reductions of ninety per cent. Beyond this point several breaks are encountered in the curve. Beyond the breaks the increase is proportional to one-half the reduction of area. For higher carbon steels the breaks in the tensile strength curves come earlier. Neither previous heat treatment nor initial size affect the rate of increase in tensile strength.

HIGH SPEED STEEL

NOTES ON THE MANUFACTURE OF HIGH SPEED AND TUNGSTEN STEELS. By J. W. Weitzenkorn, *Chemical and Metallurgical Engineering*, Vol. 26, Page 504.

The composition of the eutectiferous carbides in high speed steel is shown to be very nearly that of the ferrotungsten added to the steel. The distribution of these carbides throughout the steel materially affect its physical properties. In the cast condition these carbide masses are irregularly distributed. Mechanical work and heat treatment will give more even distribution. Heat treatment alone will only partially accomplish this.

MALLEABLE IRON

MALLEABLIZING OF WHITE CAST IRON. By A. Phillips and E. S. Davenport. Presented at the New York Meeting of the American Institute of Mining and Metallurgical Engineers.

It is found that as the wall section of cast iron increases the graphite particles become coarser. Data is given on the critical points and some physical tests are reported. The graphitic carbon is said to be precipitated from the austenite rather than from the cementite.

METALLOGRAPHY AND HARDNESS THEORY

A NEW INDUSTRIAL METHOD OF THERMAL ANALYSIS. By M. Chevenard, *Revue de Metallurgie*, Vol. 19, Page 39.

A new critical point instrument is described which not only records differences in the cooling rate but also records dilations. Critical point curves on seven materials are included in the article.

GRAIN GROWTH AND RECRYSTALLIZATION IN METALS. II. EXPERIMENTAL DATA AND GENERAL LAWS. By Zay Jeffries and R. S. Archer, *Chemical and Metallurgical Engineering*, Vol. 26, Page 402.

The influence of time, temperature, degree of cold working, original grain size and obstructing impurities are given consideration. Strain and heat gradients are shown to have a powerful effect in grain growth.

GRAIN GROWTH AND RECRYSTALLIZATION IN METALS. III. UNDERLYING CAUSES. By Zay Jeffries and R. S. Archer, *Chemical and Metallurgical Engineering*, Vol. 26, Page 449.

The laws of grain growth are presented and the nature of grain growth force is discussed.

THEORY OF HEAT TREATMENT OF STEEL. II. By W. M. Mitchell. *Forging and Heat Treating*, Vol. 8, Page 114.

The nature and constitution of austenite, martensite, troostite and sorbite are described and the object of heat treating is outlined. The mechanism of annealing is described.

X-RAY DATA ON MARTENSITE FORMED SPONTANEOUSLY FROM AUSTENITE. By E. C. Bain, *Chemical and Metallurgical Engineering*, Vol. 26, Page 543.

The method of determining grain size by X-ray is given. It is shown that coarse grained austenite breaks up into very fine grained martensite. In this connection, ordinary etching methods are shown to be at times misleading. The evidence gained corroborates the theory of the fine grained nature of martensite.

HEAT TREATING STEEL FOR STRUCTURAL PARTS. By H. C. Knerr. *Blast Furnace and Steel Plant*, Vol. 10, Page 178.

A very general discussion is given of the influence of carbon on the metallographic and physical properties of steel, the significance of critical points and the nature of the various metallographic constituents encountered in steel. The article is primarily intended for designers and mechanics.

PHYSICAL TESTING

PHYSICAL TESTING LABORATORIES DESCRIBED. By G. F. Comstock, *Forging and Heat Treating*, Vol. 7, Page 349.

A plan view and brief description of the Titanium Alloy Mfg. Co.'s laboratory is given. The laboratory is housed in a long, narrow, well-lighted brick building.

SHOP PROBLEMS

ROLLING TEETH IN HOT GEAR BLANKS. By F. E. Walker, *American Machinist*, Vol. 56, Page 409.

Practically any type of gear, including herring-bone gears, may be produced by die rolling. The cost is considerably lower than for cut gears and the tensile strength of the rolled product is appreciably higher. Cuts of the machine are shown. Eighty to ninety gears may be produced per hour per machine.

SPECIAL FIXTURES FOR HEAT TREATING. By E. H. Tingley, *Forging and Heat Treating*, Vol. 8, Page 96.

Mechanical devices worked out in the heat treating department of the Delco Light Co. are described. These appliances are used for holding parts in cyaniding and in hardening and tempering with a view to cutting down the operating time and increasing the uniformity of the product.

DROP-FORGING PRACTICE. By J. H. Nelson, *Journal* of the Society of Automotive Engineers, Vol. 10, Page 207.

Drop-forgings which are from the chemical standpoint the same, may differ widely in physical properties. This may be due to any of the large number of variables encountered in their production. Tabular results of chemical analysis and physical properties of 107 heats of carbon steel are presented. Steels of the same grade and analyses are not found to respond to heat treatment uniformally. It is suggested that steel from the same melt be heat treated together and that more rigid inspection be instituted.

HEAT TREATING A SEWING MACHINE ROTARY SHUTTLE. By J. S. Lowe, *Forging and Heat Treating*, Vol. 8, Page 119.

The shuttle is a small thin part which it is desired to carbonize only in spots. Asbestos cement is used to prevent carbonizing where it is not desired. The shuttles are carbonized in bone charcoal and are then hardened by quenching from a cyanide bath. It is desired to temper only the point of the shuttle and this is done by means of a fine gas flame.

DISCUSSION OF FORGE FURNACES. By C. Longenecker, *Blast Furnace and Steel Plant*, Vol. 10, Page 194.

Forging furnaces are classified as (1) soaking pits (2) regenerative furnaces-large hearth area (3) non-regenerative furnaces—large hearth area and (4) furnaces of small hearth area. A brief discussion is given of each type, together with figures on the heat efficiency of each with various fuels.

POLISHING OF METALS AN ART IN ITSELF. By S. G. Koon, *Iron Age,* Vol. 109, Page 777.

The finish given a manufactured article is becoming more and more a strong sales point. Hence the importance of proper polishing. The problems encountered in polishing and grinding are outlined and some of the machinery and methods used are described and illustrated. Several typical solutions of difficult grinding problems are given.

WELDING

PRACTICAL POINTS IN ARC WELDING. By J. A. Wilson, *American Machinist,* Vol. 56, Page 357.

Attention is called to the fact that proper cleaning of fractured surfaces is essential to a successful weld. The use of a flux is not recommended. Method of correcting for expansion discussed.

ELECTRIC WELDING. By A. T. Wall, *Engineering,* Vol. 63, Page 241.

The use of electric welding in ship building has considerable possibilities. It is especially applicable in replacing riveted joints. Details of ship construction and erection are given, together with citations of the present successful use of welding in ship building.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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BOCEK, Wm., (M-3), 2117 Clifton Ave., Chicago, Ill.
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BONNING, F. W., (M-1), Cummings Co., Boston, Mass.
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BOWES, W. R., (M-1), 109 Union St., Bristol, Conn.
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LEWIS, B. F., (M-4), 3450 Eastern Place, Detroit, Mich.
LUCAS, E. A., (M-3), Molybdenum Corporation of America, Washington, Pa.
MATHEWS, J. H. CO., (S-4), Pittsburgh, Pa., Att: H. R. Wade.
McCRUM, R. Y., (M-4), Colonial Steel Co., Pittsburgh, Pa.
McDONNELL, M. E., (M-1), Pennsylvania Railroad, Altoona, Pa.
MOLES, P. A., (A-4), Allyn House, Hartford, Conn.
MORRILLON, E. E., (M-12), 202 Miley Ave., Indianapolis, Ind.
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UNION SWITCH & SIGNAL CO., (S-4), Swissvale, Pa. Att: A. L. Humphrey.
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WARNER & SWASEY CO., (S-4), 5701 Carnegie Ave.,Cleveland, Ohio.
WEAVER, H. F., (M-4), Bethlehem Steel Co. Bethlehem, Pa.
WEITZENKORN, (M-3), Molybdenum Corporation of America, Washington, D. C.
WESTON, W. B., (A-4), 1815 Ford Bldg., Detroit, Mich.
WILLS, C. H., (M-3), Marysville, Mich.
WISE, EDMUND, (M-2), Wadsworth Watch Case Co., Dayton, Ky.
WOLCOTT, D. S., (A-4), Crucible Steel Co. of Amer., 17 E. 42nd St., New York City.

CHANGES OF ADDRESS

BARNETT, R. B.—from 221 Collins St. to 136 Whitman Ave. W. Hartford, Conn.

CASSIDY, A. G.—from 536 5th Ave. N. St. Petersburg, Fla., to 27 Banks St., Waltham, Mass.

DICKSON, T. C. JR.—from the University Club to 1001 Fairfield, Ave., Bridgeport.
DIMMICK, R. B.—from 510 Fulton Rd. to 1453 15th St., Canton, Ohio.
DOUD, C. E.—from 1422 Lunt Ave. to 7620 Sheridan Rd., Chicago, Ill.

GILHOOLY, J. H.—from 1769 Seyburn Ave., Detroit, to Tate-Jones & Co., Pittsburgh.

HARBERT, W. G.—from 207 W. Webster Ave. to 208 West Clay Ave., Muskegon, Mich.
HUMPHREYVILLE, L.—from 15420 Huntmere to 14304 Shaw Ave., Cleveland, Ohio.

KIEFER, H. G.—from 2911 Iroquois, Detroit, to 1030 Beaconsfield, Ave., Grosse Pointe Park, Mich.
KOEHLER, W. W.—from 3113 Osgood St. to Goodman Mfg. Co., Chicago, Ill.
KRAEKEMIER, HENRY—from 1647 Iranistan Ave. to 547 Pequonock St., Bridgeport.

McENTEE, P. J.—from 3 Freeman Court S. Charleston, to Ridley Park, Pa.
MACKENZIE, A.—from 1912 Western Ave. to 208 W. 8th St., Manitowoc, Wis.
MANLEY, R. S.—from 410 Perry Apts., Davenport, Ia., to 1035 17th St., Rock Island, Ill.
McINERNEY, W. I.—from 1 Curry St., Charleston, to Pittsburgh Crucible Steel Company, Midland, Pa.
MARBLE, W. H.—from 1541 Oliver Bldg. to 619 State Theater Bldg., Pittsburgh.

NEIL, E. B.—from Pierce Arrow Motor Co., Buffalo, to Harrold Motor Car Co., New York City.

OLIVER, W. O.—from 476 W. Marion St. to 308 Kennedy Rd., Toronto, Ont., Can.

PRIESTLEY, W. J.—from Quarters B, Armour Park, S. Charleston, to Pittsburgh Crucible Steel Co., Midland Wks., Midland, Pa.

PUTNAM, A. H.—from 410 Perry Apts. to 1710 E. 12th St., Davenport, Iowa.

SELLECK, T. G.—from 513 Peoples Bk. Bldg. to 302 N. Pine Ave., Chicago, Ill.
SMITH, S. G.—from 123 Sisson Ave. to 230 S. Whitney St., Hartford, Conn.

WEDLAKE, P.—from 125 Atlantic St., Anacostia, D. C., to Wilson-Maeulen Co., New York City.
WHITE, W. H.—from 3 Washington St., S. Charleston, to 307 A St. S. E., Washington, D. C.
WHITE, W. H.—from 192 Chambers St. to 56 Murray St., New York City.
WORTH, C. B.—from 501 W. Liberty St., Ann Arbor, Mich., to Wilcox Motor Parts & Mfg. Co., Saginaw, Mich.

MAIL RETURNED

CARLTON, CAPT. FRANK, 1439 Rhode Island Avenue, Washington, D. C.

EKSTROM, H. C., Dodge, Inc., S. Boston, Mass.

ETTER, P. A., 1736 Johnson Street, Philadlephia, Pa.

OTEY, N. S., 1417 Ritner Street, Philadelphia, Pa.

ROBINSON, H. A., 19 E. 88th Street, New York City.

WOOD, Edson, 315 Bay Street, Springfield, Mass.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

HOW HIGH DOES YOUR CHAPTER STAND?

IN THE April issue was published the standing of the chapters as of March 1 and printed below is the standing as of April 1.

1. Chicago
2. Detroit
3. Philadelphia
4. PITTSBURGH
5. *Cleveland*
6. New York
7. *Indianapolis
8. *Hartford
9. Syracuse
10. Boston

* tied

11. Lehigh Valley
12. Milwaukee
13. North West
14. WORCESTER
15. †*Rockford*
16. †*Cincinnati*
17.***Tri City*
18.***St. Louis*
19. *Charleston*
20. *Springfield*

† tied
** tied

21. Providence
22. Schenectady
23. *New Haven
24. *Washington
25. Buffalo
26. Toronto
27. South Bend
28. Rochester
29. Bridgeport
30. Gary

* tied

The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on March 1. Those shown in italics are not occupying as high a position as in the previous report.

It is interesting to note that Pittsburgh increased its position over that of Cleveland, due to its increased activities in securing sustaining members. Pittsburgh is not satisfied with the position it occupies at the present, and special activity is under way to continue the advancing movement.

Detroit and Chicago are in an intensive campaign for first position. Detroit has been anxious to secure the place occupied by Chicago since the organization of the Society and has excellent prospects of accomplishing its desire.

Hartford increased its membership during the month to a point where it is tied with Indianapolis for seventh place. It is possible that the report to be published in the next issue of the TRANSACTIONS will show a change in the relative positions occupied by these chapters.

Worcester made a most commendable progress during the month having advanced from 20th position to that of 14th, which of course caused the six chapters passed to lose a position and consequently to be printed in italics.

Cincinnati is tied with Rockford for 15th place, while St. Louis is tied with the Tri City for 17th and Washington is tied with New Haven for 23rd.

All of the members of all of the chapters should realize that they play an important part in the standing of their chapter and they should not place upon the Membership Committee the responsibility of advancing the chapter's position. The Society would be a decided asset and benefit to many individuals who are probably in the same plant with you or who are within your circle of acquaintanceship. All that you would need to do in order to secure their membership would be to present the Society to them in the proper manner. Your co-operation is necessary. Can they prove it by you that your chapter is asleep?

BOSTON CHAPTER

The regular monthly meeting of the chapter was held Friday evening, April 14, at 8 o'clock. The announcement of this meeting promised that the chapter would declare dividends at this meeting and it surely did. The dividends were in the form of valuable information and methods of steel inspectioin without the use of complex apparatus.

This information was very capably presented by V. O. Homerberg who has recently conducted a very successful course of instruction in metallography, given at the Franklin Union under the auspices of the Boston Chapter. Those who were fortunate enough to be able to attend this meeting surely did go away with their share of the chapters melon. It is the plan of the chapter that Mr. Homerberg will again conduct this course in metallography which is planned to start next fall.

DETROIT CHAPTER

A most interesting meeting was held in Detroit, April 10, at the Board of Commerce. About 100 were out to greet National President F. P. Gilligan, who was the guest and speaker of the evening. His talk on "What Happens to Steel When It Is Heated and Quenched", well repaid all who came out to hear it.

One of the features of the meeting was the presentation to W. C. Peterson, by President Gilligan, of a medal which was given as a token of appreciation for the faithful work he had done on behalf of the Society. For once the Detroit boys saw "Pete" at a loss to know what to say. In fact it so affected our old friend that it was not until after President Gil-

ligan had finished his main talk could "Pete" find himself, as he did, and thanked the Society in a most sincere and characteristic manner.

J. Fletcher Harper was present and gave a few words about the progress of the National Membership Committee work of which he is chairman. H. G. Giessinger on the evening of April 24 presented a very interesting paper entitled "Temperature Control". Mr. Giessinger is an expert along this line. His paper was well presented and aroused considerable discussion afterward.

PITTSBURGH CHAPTER

A joint meeting of the Pittsburgh Chapter and the Engineers' Society of Western Pennsylvania was held in the blue room, William Penn Hotel, Tuesday, April 18. The meeting opened promptly at 8 o'clock and was addressed by E. F. Collins, consulting engineer, industrial heating department, General Electric Co., who presented a paper entitled, "Some Applications of Electricity to the Reheating of Steels". The paper contained some very valuable information and discussion on metallic and nonmetallic resistor furnaces. This paper was a highly technical paper and brought out many points of information which were valuable for both engineers and heat treaters.

Mr. Collins discussed advantageous applications of the electric furnace and showed how it could be used in many industrial processes wherein steels had to be reheated either for japanning, sherardizing, enameling, or carburizing and hardening. The meeting was very well attended and proved to be highly interesting to all those who were fortunate enough in attending.

CLEVELAND CHAPTER

The Cleveland Chapter held its regular monthly meeting in the Engineering Society rooms of the Hotel Winton, Friday evening, April 28. The paper for this meeting was presented by H. A. Schwartz, director of research, National Malleable Castings Co., Cleveland. It was entitled "Some Laboratory Work on Malleable Cast Iron", and was well illustrated with stereopticon slides. Mr. Schwartz made this a practical talk from the engineers' standpoint. The meeting was well attended and many interesting points of discussion were brought out. The Nominating Committee made a report on its selection of candidates for election to office for the ensuing year. The meeting was attended by about 100 members and guests.

ROCHESTER CHAPTER

The April meeting of the Rochester Chapter was held in the Rochester Engineering Society Club rooms Wednesday evening, April 12. President F. P. Gilligan was the guest of honor and speaker for the meeting. He presented his paper entitled "What Happens to a Piece of Steel When It Is Heated and Quenched". This paper was presented in the able manner in which President Gilligan always delivers his lectures and was of great interest to the members and guests present. The discussion following this paper was especially valuable and interesting.

NEW HAVEN CHAPTER

Thursday evening, April 20, the New Haven Chapter held its monthly meeting at the Geometric Tool Co., Westville, Conn. The program for

this meeting consisted of four reels of motion pictures entitled "The Manufacture of Steel for Sheets and Plates". This picture was taken at the plant of the American Sheet & Tin Plate Co., and showed the entire working of the product from the ore to the finished plate. These pictures were obtained through the courtesy of the Bureau of Mines. The meeting was well attended and proved to be very profitable to all who were present.

SYRACUSE CHAPTER

The April meeting of the Syracuse Chapter was held in the Yates Hotel banquet room, Friday, April 7 at 7:45 p. m. W. R. Shimer, sales metallurgist, Bethlehem Steel Co., presented three reels of motion pictures of Bethlehem operations. The pictures were very interesting and brought forth numerous questions and discussions. The meeting was well attended by about 125 members and guests.

SCHENECTADY CHAPTER

The Schenectady Chapter held a meeting in the Civil Engineering building, Union College, March 21. G. R. Brophy, metallurgist, General Electric Co., gave a talk on "Metallography". The lecture was given in as plain language as was possible and was intended especially for the instruction of the practical men.

The April meeting of the Chapter was held in the Civil Engineering building, Union College, Tuesday, April 18, at 8 o'clock. This meeting was addressed by H. J. Stagg, assistant general manager of the Halcomb Steel Co., Syracuse, N. Y., who presented a paper entitled "Why Did It Break?" This paper was well illustrated with stereopticon slides. Mr. Stagg's broad experience is metallurgy and the manufacture of steel especially fits him in diagnosing the cause and remedies of many of the failures of steel parts which he showed on the screen. Many questions were asked which brought forth much valuable discussion which was of benefit to all present.

NORTH WEST CHAPTER

North West Chapter had its regular meeting at the Manufacturer's Club on Friday, April 14 when a very interesting program was given on the subject of "Forgings". The speakers were all recognized authorities on the subject and contributed to an interesting meeting.

George L. Whelan, of the Whelan Drop Forge Co., Minneapolis, was the first speaker and explained in an entertaining manner the method of making a complicated small forging used as a substitute for the hand. Mr. Whelan's broad experience with the drop forging industry, having been formerly with the Cleveland Hardware Co., especially qualified him to answer the many questions as to the relative efficiency of different types of hammers.

The second speaker was F. G. Lilygreen of the American Hoist and Derrick Co., St. Paul, who gave a description of the forging plant of that company and the general class of work it had to do as well as the various methods by which it was accomplished.

The third speaker was Melvin Ovestrud of the Twin City Forge & Foundry Co., Stillwater, who gave an interesting exposition of the various processes to produce a finished forging. Mr. Ovestrud is an authority

on forging practice and his talk proved valuable, illustrated as it was by large photographs of the installation at his plant and samples of complicated forgings.

National Secretary, W. H. Eisenman was present and talked to the members upon the work of the Society and expressed his gratification on the excellent manner in which the chapter had been conducted and the fine spirit of co-operation shown by all of the members.

SOUTH BEND CHAPTER

The South Bend Chapter had an exceptionally fine meeting on Tuesday, April 11, when O. T. Muehlemeyer of the Barber-Colman Co., Rockford, Ill., presented an interesting paper on the subject of "Hardening Room Practice". Mr. Muehlemeyer's excellent elucidation of the many difficulties involved and the best method of overcoming them, was pleasingly received. A keen and practical discussion followed the presentation of the paper.

LEHIGH VALLEY CHAPTER

John E. Halbing, assistant superintendent of heat treating, Ingersoll-Rand Co. and chairman of the Lehigh Valley Chapter, presented an interesting paper Monday evening, April 24, entitled the "Hump Method of Heat Treating". Mr. Halbing is an expert in heat treating and handled his subject in a capable and interesting manner. His talk aroused considerable interest and brought forth a good lively discussion.

In the April issue of the TRANSACTIONS it was announced that B. F. Shepherd, assistant superintendent of heat treating, Ingersoll-Rand Co., presented a paper before the Lehigh Valley Chapter, March 24, entitled "Carburizing". This paper proved to be of much interest to those who heard it, due to the fact that much of the material presented was entirely original. One of the many interesting phases of the subject as presented by Mr. Shepherd is shown in the Iron-Carbon diagram which is reproduced on the opposite page. This diagram portrays the effect of carburizing on the microstructure of steel in a very unique manner.

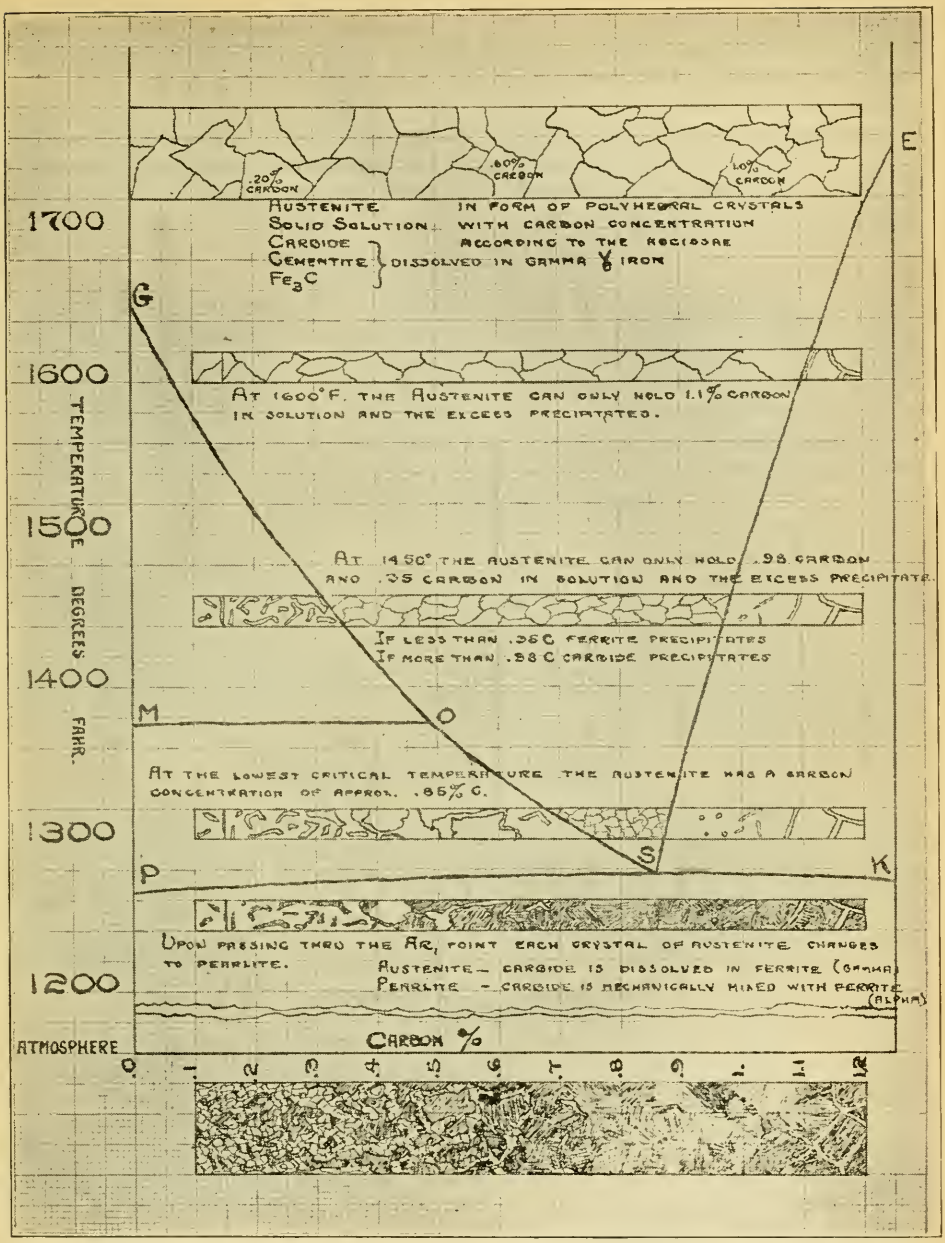
CINCINNATI CHAPTER

The regular monthly meeting of the Cincinnati Chapter was held April 20 at 8 o'clock in the Ohio Mechanics Institute. J. V. Emmons, National Treasurer and metallurgist of the Cleveland Twist Drill Co., Cleveland, presented a very interesting talk on "Tool Hardening Problems" illustrated with stereopticon slides. Mr. Emmons handled his subject capably and aroused considerable interest as evidenced by the enthusiastic discussions which followed his paper. The report of the Nominating Committee's selection of names of candidates for office for the ensuing year was made. Balloting on these names will take place at the May meeting.

CHICAGO CHAPTER

The Chicago Chapter held its regular April meeting on Thursday, April 13 at the City Club when Prof. H. F. Moore presented a paper on "Fatigue of Metals Under Repeated Stress". About 125 were present at the meeting and enjoyed Prof. Moore's presentation of the interesting subject.

National Secretary, W. H. Eisenman was present and spoke to the



Iron-Carbon Diagram Portraying Effect of Carburizing on Microstructure of Steel

membership with reference to the progress the Society had made during the past year as well as about the advance preparations for the Detroit Convention.

ST. LOUIS CHAPTER

St. Louis held its regular meeting on Friday, April 7 when O. T.

Muehlemeyer, metallurgist, Barber-Colman Co., Rockford, Ill., presented a paper on "Hardening Room Practice". Mr. Muehlemeyer presented a very interesting and practical paper dealing with the ideal method in which the day's work of tools should be handled in the hardening room. The paper contained a great deal of practical information and aroused a large amount of favorable comment and discussion. W. H. Eisenman, National Secretary, was present at the meeting and spoke to the members on matters pertaining to the Society.

INDIANAPOLIS CHAPTER

The April meeting of the Indianapolis Chapter was held Monday evening April 3 in the auditorium of the Emmerich Manual Training High School. The program for the meeting was four reels of motion pictures of processes at the National Tube Co. plants and two reels of films of the Illinois Steel Co., triplex process. Needless to say these pictures were very instructive and interesting. Following their exhibition, questions and discussions were in order. Many interesting points were covered.

RHODE ISLAND CHAPTER

The April meeting of the Rhode Island Chapter was addressed by George P. Moore, of the Wallace Barnes Co., Bristol, Conn., Wednesday, April 5. The subject of Mr. Moore's paper was the "Manufacture of Springs and Their Heat Treatment," which included the characteristics of overworked and overstrained metal. Numerous samples showing these features were displayed by the speaker. The meeting proved to be exceedingly interesting and profitable to all.

SPRINGFIELD CHAPTER

The April meeting of the chapter was held Friday, April 21, at which time Mr. De Long of the Carpenter Steel Co. gave an illustrated talk on the manufacture of steel. As this subject always brings forth many points of interest and discussion, Mr. De Long's paper brought forth its share. Following the paper an open discussion was held on the relative merits of 3½ per cent nickel steel versus chrome nickel steel for case hardening.

HARTFORD CHAPTER

The April meeting of the Hartford chapter was addressed by Dr. John A. Mathews, president of the Crucible Steel Co. of America. His subject was "Iron in Antiquity and Today", and consisted of a complete and interesting history of the development and use of iron and steel from prehistoric ages up to the present time. The talk was illustrated by slides taken from ancient books, showing the methods and devices for fabricating steel in the olden days. The audience numbered 110, of which about half were members.

Before the meeting, an impromptu dinner was held at the Hotel Bond, at which were present representative executives from the different industries of Hartford and Bristol, who had been invited to meet Dr. Mathews in this way, also the members of the Gauge Steel Committee, who had met with him and Chairman Blood in the afternoon.

Plans for increasing the membership of the chapter were discussed at the meeting, and a standards committee and a nominating committee appointed. The question of relative excellence of acid and basic open-

hearth steel was brought up and discussed. Mr. Blackman, of Colt's Patent Firearms Mfg. Co., also asked for the experience of others in producing file hardness in a 0.45 carbon, 3.50 nickel, 1.50 per cent chrome steel. It appeared the general opinion that file hardness could not be obtained in a steel of this type, unless case hardening was resorted to. This treatment was not favored by those present.

The spring inspection meeting was held Saturday, April 29. A complete report of this meeting will appear in the June issue of the TRANSACTIONS.

TRI CITY CHAPTER

The Tri City Chapter of the society held its regular monthly meeting March 29 in the rooms of the Davenport Chamber of Commerce. A. H. Putnam, chairman appointed the members of the nominating committee for the nomination of candidates for the ensuing year.

Prof. John F. Keller of the Lewis Institute presented a talk on "Why Steel Warps", going into details on both the heating and cooling of steels. He gave a practical demonstration of the decalescent and recalescent point with an electrically-heated wire. This paper was followed by a discussion of practical heat treating problems after which Prof. Keller was given a rising vote of thanks.

The Tri City chapter held its April meeting, Thursday the 27th. C. W. Veach, superintendent of the open-hearth furnaces of the Bettendorf Steel Car Co., presented a very interesting paper entitled "Reactions in the Open-Hearth Furnace." This paper proved to be exceedingly interesting and was followed by a large amount of good discussion. The meeting was preceded by a get together dinner which was served at 7 p. m.

NEW YORK CHAPTER

The New York chapter regular April meeting was held in the assembly room of the Merchants Association of New York, 9th floor of the Woolworth Building, Tuesday, April 25. Through a joint arrangement with other eastern chapters of the Society, Prof. H. F. Moore of the Engineering Experimental Station of the University of Illinois was secured as the speaker of the evening and presented his paper entitled the "Fatigue of Metals." Professor Moore has specialized extensively in the study of fatigue resisting values of various steels and his paper proved to be of great interest to all as evidenced by the discussion which followed his paper.

Reviews of Recent Patents

Arthur E. Bellis, Springfield, Mass., recommends that metal be heated in a salt bath prior to forging, rolling or other hot work. Accurate temperature control is possible, and when withdrawn the metal is covered with a thin film of salt which prevents surface oxidation and helps to avoid uneven chilling by variable air currents. In this manner scaling is reduced to a great extent and trouble and expense consequent to oxidation are avoided. (1,399,044. Dec. 6, 1921.)

1,404,438. Heat insulating and resisting material. Edgar T. Holmberg, Cleveland, Ohio, assignor to The James H. Herron Co., Cleveland, Ohio.

A heat insulating and resisting material of about 30 per cent of magnesia and 70 per cent of an infusorial siliceous earth with a saturated solution of magnesium chloride.

1,402,722. Apparatus for the heat treatment of metals. Lyman C. Josephs, Jr., Allentown, Pa., and Gottfried Wirrer, Plainfield, N. J., assignors to International Motor Company, New York, N. Y.

In an apparatus for the heat treatment of metal, the combination of means to effect a change in the heat treatment and devices subject to a reduction in the rate of expansion of the metal under treatment whereby the actuation of said means is initiated.

1,401,983. Method of heat treatment and furnace therefor, Axel Gustaf Emanuel Hultgren, Gottenborg, Sweden, assignor to Aktiebolaget Svenska Kullagerfabriken, Gottenborg, Sweden.

The method of heat treatment of symmetrical circular objects constituting solids of revolution, which consists in passing them in a continuous succession through a long chamber in which they are directly exposed, the bottom of which chamber has such inclination that the objects advance with a rolling traction on the bottom while sliding against one another at their points of tangential contact, simultaneously heating such chamber, and controlling the progress of the objects through the chamber at such rate with reference to their mass and to the temperature and length of the chamber as to subject each of the successive objects during its rolling progression to the prescribed heat treatment.

1,403,313. Combination double-muffle preheating and heat treating furnace. James A. Gaskill, Cleveland, O.

A heat treating furnace comprising a combustion chamber, a cover having a central opening, an annular air compression chamber, a tangentially placed inlet pipe for air at the base of said air chamber, tangential fuel burner, nozzles discharging in said combustion chamber, a mixing chamber for fuel and air communicating with each burner nozzle, air passages leading from air chamber and communicating with mixing chambers and a muffle horizontally supported in combustion chamber, muffle extending through the walls of combustion chamber and air chamber, and a door in the outer wall of air chamber giving access to muffle.

Commercial Items of Interest

A MINING engineer and a metallurgist are to be selected by the Bureau of Mines and by the Bureau of Standards in the near future to make an intensive study as to present practice in the heat treatment of drill steels and the extent to which breakage occurs. These engineers are to make a much more exhaustive survey than ever has been attempted before. They will submit a report to the advisory board which is co-operating with the bureaus in the study of rock drill steels and other steels which must withstand impact stresses. The advisory committee is composed of B. F. Tilson, H. S. Brainard, J. A. Mathews, George H. Clark, H. M. Boylston, Van H. Manning, F. W. Deonton, Walcott Remington and Bradley Stoughton. The survey about to be undertaken is under the immediate supervision of D. A. Lyon, chief metallurgist of the Bureau of Mines, and G. K. Burgess, of the Bureau of Standards.

AN electrically operated blast, intended for heat treating and other furnaces has been placed on the market by the Clements Mfg. Co., 601 Fulton street, Chicago. Among the advantages claimed are that as the blast is operated from an electric light socket, it may be used while the rest of the plant is shut down. It is designed to draw a sufficient quantity of gas from the mains to develop heating effects without variation. A feature emphasized by the makers is the saving from the speed at which the furnace is brought up to the desired temperature, it being said that the furnace may be brought up to 1600 degrees Fahr. in a few minutes.

The blast is driven by a 1/6-horsepower universal motor and is designed so as to be able to deliver 210 cubic feet of air per minute at the normal operating speed of motor. A damper for regulating the mixture of air and gas has been incorporated. The operation is similar to that of a carburetor on an automobile. The mixture should be rich at first and continue so until the furnace is warmed up, the damper being opened gradually to admit air.

The Chicago branch of the Driver-Harris Co., manufacturers of nichrome heat treating containers, has taken enlarged quarters and will be located in them after May 1. These new quarters are at 562-574 West Randolph street.

A series of tests was completed recently by the Bureau of Standards, Washington, on samples of electric and open-hearth heats of silicomanganese spring steels carrying equal proportions of carbon, manganese, phosphorus, sulphur and silicon. The tests included microscopic examination, tensile strength, and determination of proportions of certain gases present, particularly nitrogen and hydrogen. In general, the microstructure of the electric steel was somewhat different from that observed in the open-hearth when both steels were subjected to the same heat treat-

(Continued on Page 34)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING, Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U. S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

FOREMAN OR INSTRUCTOR—Nine years instructor forge work, College Cornell University; four years foreman toolsmith and steel treater of large ship-building corporation. Thoroughly experienced in all classes of steel. Wages reasonable. Location preferred, Ohio, Massachusetts, New York, Pennsylvania, and Connecticut. 2-5

ENGINEERING or PRODUCTION WORK—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired $200-$250. per month. Address 5-25.

SALESMAN—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

METALLURGIST—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired $4500. per year. Address 5-35.

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 3-15.

ASSISTANT METALLURGIST—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired $150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

METALLURGIST AND ENGINEER—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

FURNACE DESIGNER and BUILDER—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

CHEMIST—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

CHEMIST OR ASSISTANT TO CHIEF METALLURGIST: Technically trained. Practically experienced in chemical and physical analysis, pyrometry general heat treating, foundry control, shop work and methods. Able to investigate trouble and handle same. Michigan or adjacent territory preferred. Answer 3-20.

TOOL HARDENER OR FOREMAN—30 years earnest effort in tool forging and tool hardening with extensive high speed steel experience. Can offer efficient operation or supervision. Exceptionally successful in eliminating scrap—Excellent references, Location immaterial, wages desired $50.00 per week. Address 3-40

SALES ENGINEER—Thorough metallurgical training and experienced salesman. At present employed but desires change. Wide acquaintance New York, New England and Canada. Basic knowledge foreign markets and can produce. Age 28. Married. Address 4-5.

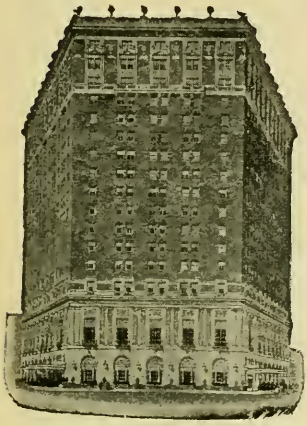
METALLURGIST—Eight years experience in research, metallography, heat treatment, complaint and service work; High speed, tool steel and cast cutter work. Address 3-30

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 12-10.

TRANSACTIONS
of the
American Society for Steel Treating

Vol. II | Cleveland, June 1922 | No. 9

HOTEL RESERVATIONS FOR DETROIT CONVENTION



Statler Hotel, Convention Headquarters

DETROIT has promised to provide all of our members and guests with excellent accommodations as far as hotels are concerned. Through the efforts of D. J. Crowley, 832 Dime Bank Building, Detroit, Chairman of the Hotel Committee, a list of hotels is given below with their rates for single and double rooms as well as the number of reservations each hotel will accept. The Statler Hotel will be the official headquarters. All persons in attendance at Detroit will make their own hotel reservation direct with the managers and it is advisable that the members take the following precaution: When making reservations, state that you are attending the International Steel Exposition and Convention of the American Society for Steel Treating, give the date of arrival, kind of room desired and the price you wish to pay. Request the hotel manager to answer your letter repeating the reservation, then take the letter with you to Detroit and present it when you register. This precaution taken now may avoid serious difficulty during the rush of the Convention. It is recommended that reservations be made immediately.

The list of hotels follow:

Lincoln Hotel

Rate Without Bath	Rate With Bath
Single $1.25, $1.50, $1.75, $2.00	Single 6 showers and tubs on each floor
Double $2.50, $3.00 (2 men)	Double no private baths

Will accommodate 75

Remarks: Large lobby. Good cafeteria.

Hotel Fort Shelby

Rate Without Bath	Rate With Bath
Single $2.00	Single $3.00, $3.50, $4.00, $5 00
Double $3.00	Double $5.00, $6.00, $7.00

Will accommodate 50 to 100

Cadillac Hotel

Rate Without Bath	Rate With Bath
Single 2.00, $2.50	Single $2.50, $3.00, $3.50, $4.00
Double $3.00, $3.50, $4.00	Double $4.00, $5.00, $6.00, $7.00

Will accommodate 500

Charlevoix Hotel

Rate With Bath
Single $3.00, $3.50, $4.00
Double $5.00, $6.00

Two-Room Suites.....$7.00
Three-Room Suites $8.25
Four-Room Suites $9.00

Number of persons with notice—100

Hotel Wolverine

Rate With Bath
Single $2.50, $3.00, $3.50, $4.00, $4.50, $5.00, $6.00
Double $4.50, $5.00, $5.50, $6.00, $6.50, $7.00, $8.00
Will accommodate 300

Hotel Norton

Rate Without Bath
Single $2.00 to $2.25
Double $4.00

Rate With Bath
Single $2.50 to $3.00
Double $4.50 to $5.50

Will accommodate 100

Hotel Normandie

Rate Without Bath
Single $1.50 to $2.00
Double $2.50 to $3.00

Rate With Bath
Single $2.50 to $3.00
Double $3.50 to $4.00

Will accommodate 100

Madison-Lenox

Rate Without Bath
Single $2.00
Double $3.00

Rate With Bath
Single $2.50, $3.00
Double $3.50, $4.00

Will accommodate 100 or more

Library Park Hotel

Rate Without Bath
Single $1.25 to $2.00
Double $2.00 to $3.00

Rate With Bath
Single $3.00
Double $4.00

Will accommodate 50

Hotel Stevenson

Rate With Bath
Single $2.50
Double $3.50
Will accommodate 50

Hotel Statler

Rate With Shower
Single $3.00 to $3.50
Double $5.00 to $5.50

Rate With Bath
Single $4.00 to $ 8.00
Double $6.00 to $10.00

Will accommodate—400 rooms to take care of 600 to 800 people

Hotel Tuller

Rate With Bath
Single $2.50
Double $4.50
Will accommodate 300

Hotel Griswold

Rate Without Bath
Single $2.00
Double $3.00

Rate With Bath
Single $2.50, $3.00, $3.50
Double $4.00, $5.00, $6.00

Will accommodate 125

Hotel Addison

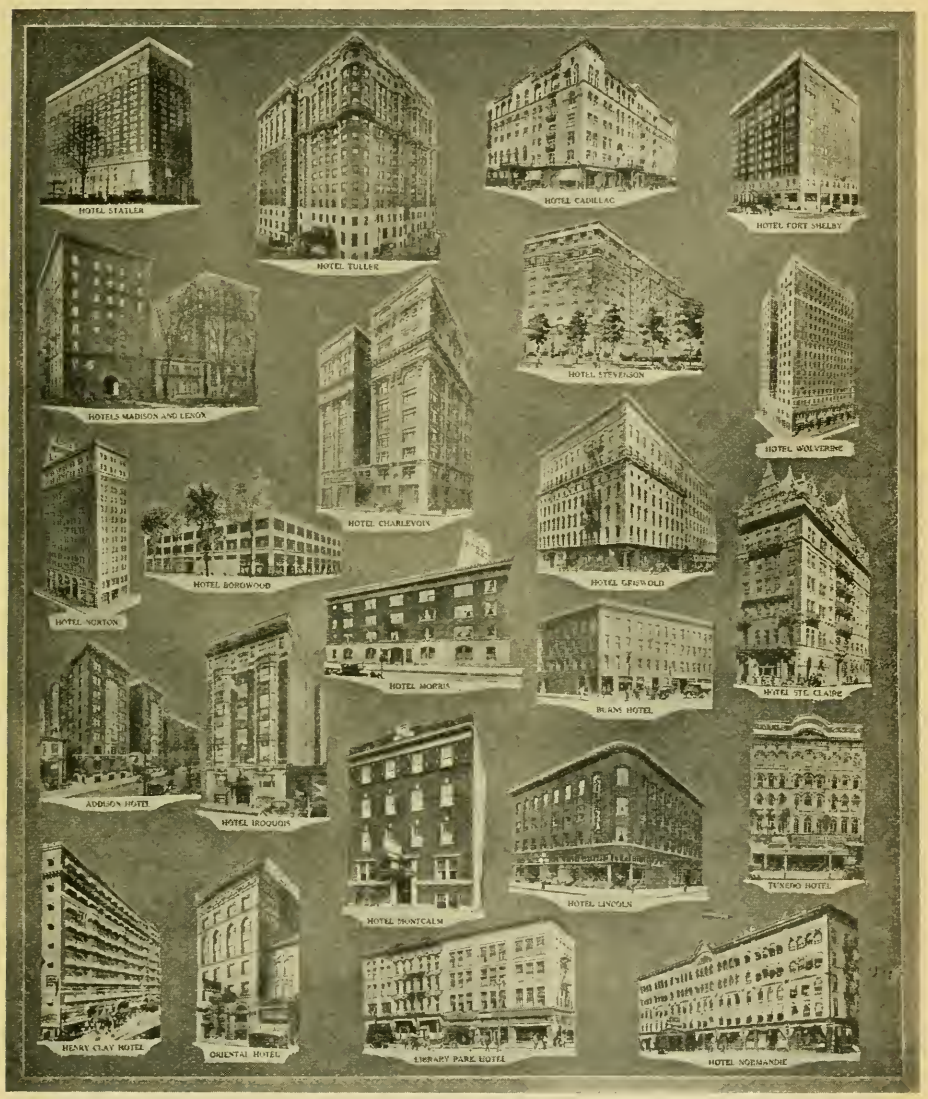
Rate Without Bath
Single $1.50
Double $3.00

Rate With Bath
Single $2.50
Double $4.00

Will accommodate 250

DETROIT CONVENTION

We are pleased to announce that the railroads of the country through the Central Passenger Association have granted fare and one-half round trip for members of the Society and their dependants attending the International Steel Exposition and Conventions of the American Society for



Detroit Hotels

Steel Treating and the American Drop Forging Institute at Detroit, October 2nd and 7th.

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification certificate must be presented to the ticket agent before one may purchase round trip tickets at the reduced rate. This iden-

tification certificate will be mailed to members of the Society before the time of the Convention. Reduced rates were offered as an experiment last year by the railroads to those attending the Indianapolis Convention. Because of the large number using the plan the special rate was granted again this year. The granting of this rate means the saving of thousands of dollars to the members of the Society as wives and other members of a family may also have the advantage of this reduction.

The American Drop Forging Institute has accepted the invitation to hold their Annual Convention at Detroit concurrently with that of the American Society for Steel Treating. Certain portions of the program have been set aside for the use of the Forging Industry, and many members of the American Drop Forge Supply Association will have their products on exhibition. The program of the two conventions will be worked out in such a manner as not to conflict, but the entertainment features, as well as one or two of the sessions will be common to both the organizations.

The exhibition will be the largest the Society has ever had. The main exhibition hall 500 x 30 feet has practically all been reserved and additional floor space will have to be opened up to take care of the many exhibitors who wish to be present.

EDITOR'S GREETINGS

SINCERE and hearty greetings and felicitations are extended to all of our members and readers by your recently appointed editor. In laying the course and guiding the TRANSACTIONS to a more propitious and helpful position than it now holds, we feel dependent to a greater or less degree upon all of our readers. At the present time the TRANSACTIONS of the Society holds a very enviable position in the technical literature and is covering a field of endeavor which up to a short time ago had been somewhat neglected. In our desire to increase the value of our publication we have worked out some very definite lines of procedure in carrying on and enlarging the work of the TRANSACTIONS and as these new features are brought forth, we want your expressions on their value in making our official organ more valuable to all.

Your co-operation is indeed essential; it is absolutely imperative that we have it. Without it, the work of TRANSACTIONS will probably not be all that you desired of it. Your assistance, your words of confidence, your criticisms and helpful discussions are quite needed and earnestly solicited. Do not hesitate to express yourself, either when you favor or disapprove of any action which has been taken or which may be under consideration. Only through knowledge of the desire of the membership can we be sure of pleasing the majority. Let us have your ideas which you believe will improve the Society's publication. In the interest of greater service to all, it is hoped that you will assist in making the TRANSACTIONS what you would like to see it.

With this issue begins a change in the character of the binding of the TRANSACTIONS. This change is from the saddle stitch to the side stitch, which permits of considerable more flexibility in the make up of the book and lends itself more admirably to binding when the volume is complete.

DR. HENRY MARION HOWE
1848 - 1922

HENRY MARION HOWE, premier American scientist in the realm of iron and steel metallurgy, died on Sunday, May 14, 1922, at his home in Bedford Hills., N. Y. from an illness which he has suffered for many months. He was born March 2, 1848 at Boston, the son of Dr. Samuel G. Howe and Julia Ward Howe. Both parents were prominent in public activities; his father for his philanthrophy and interest in the welfare of the blind and feeble minded, and his distinguished service in the Grecian war for independence in the early 19th century; his mother for her leadership in the abolition of slavery, her efforts in securing of suffrage for women in the United States. From his mother, who was author of "The Battle Hymn of the Republic" he inherited a marked versatility in writing and had a wonderful ability of presiding over and directing public meetings. From his father, who was always active in medical research he inherited that extraordinary quality of keen vision and power of observation which is so essential in investigative endeavor and research.

His early education in the Boston Latin School was followed by his study in Harvard College from which he was graduated in the year 1869, with the degree of A. B. and in 1872 received the degree of M. A. In 1871 he received the degree of B. S. from Massachusetts Institute of Technology where he specialized in work in the department of Mining and Metallurgy.

Later he received the Honorary degree of LL.D. 1905 from Harvard University.

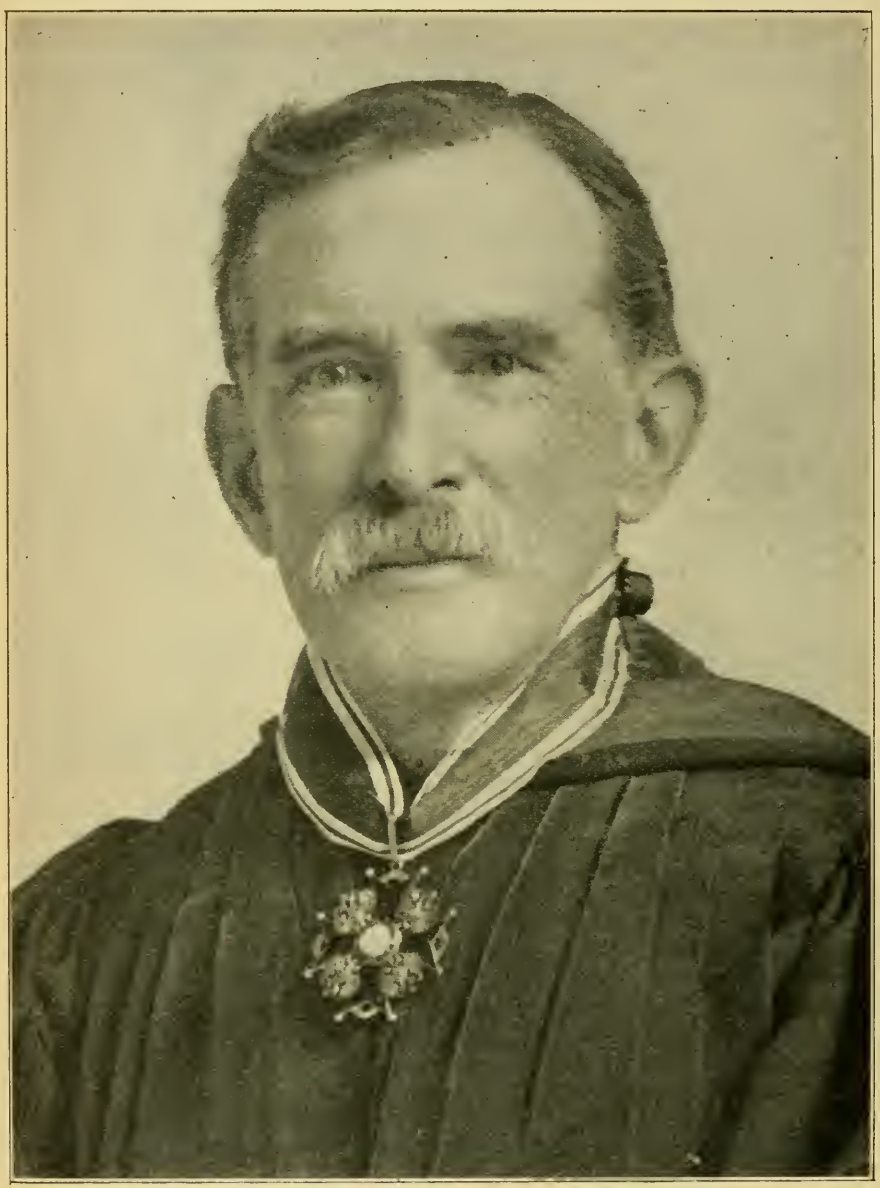
On April 9, 1874 he married Miss Fannie Gay of Troy, N. Y. who survives him. She has always been a devoted helper in his scientific service to the world.

Following his academic work he engaged in metallurigal work at Pittsburgh and Troy where he early gained an enviable reputation as an investigator and keen observer.

In 1880 he designed and built the works of the Oxford Nickel & Copper Company, at Capelton and Eustic, Quebec. From 1883 to 1897 he acted as consulting metallurgist and also lectured at Massachusetts Institute of Technology. It was in 1890 that he introduced the manufacture of Hadfield manganese steel in the United States. He became professor of metallurgy at Columbia in 1897 and in 1913 professor emeritus. He distinguished himself by his indefatigable research and investigation.

Prof. Howe published his first book, "Copper Smelting" in 1885, and in 1891 "The Metallurgy of Steel" which was translated into French. In 1902 "Metallurgical Laboratory Notes" was published and translated into French and in 1903 "Iron, Steel and Other Alloys," translated in Russian. He contributed more than 300 professional papers and was a foremost leader in the science of metallography. Many honors were conferred upon him which are given in the Bulletin of the American Institute of Mining Engineers for July 1913, among which we might mention were the Bessemer Medal, the Gold Medal of the Society for Encouragement of National Industry of France, the Gold Medal of the German Society for Promotion of Technical Industry, the Knighthood of the Order of St. Stanislas of Russia and the Elliott Cresson Gold

Medal of the Franklin Institute, Philadelphia. He was a member of many foreign societies and orders. He was a non-resident Fellow of the American Philosophical society and American Academy of Arts and



Dr. Henry Marion Howe

Sciences, honorary member of the American Society for Steel Treating, American Iron and Steel Institute and many others.

Dr. Howe was an expert in litigation on iron and steel. His chief

contribution to the scientific world, however, was his development of the science of metallography which was the result of his great powers of observation and deduction. His ability for correlating and interpreting each discovery and investigation by others and supplementing them by investigations of his own resulted in the establishment of a new science, dealing with the constitution of iron and steel.

During the World war he was chairman of the engineering division of the National Research Council which he resigned in 1919 and remained as honorary chairman until his death.

The death of Dr. Howe makes an irretrievable loss to the world of metallurgical science.

REPORT OF NOMINATING COMMITTEE

To the Secretary of the American Society for Steel Treating:

The National Nominating Committee, meeting accordingly to the Constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office:

President—T. D. Lynch, Pittsburgh, Pa.
Second Vice President—W. S. Bidle, Cleveland, Ohio.
Secretary—W. H. Eisenman, Cleveland, Ohio.
Director—Samuel M. Havens, Harvey, Ill.

According to Section 10 of Article VII of the By-Laws, we are enclosing the written consent of these gentlemen to their nomination.

Yours very truly,
NATIONAL NOMINATING COMMITTEE,
American Society for Steel Treating.
(Signed)
C. S. MOODY,
H. C. GOODWILL,
CARL SCHUMANN,
D. W. McDOWELL, Chairman.

BIOGRAPHY OF NOMINEES FOR OFFICES IN THE NATIONAL SOCIETY

Tillman Davis Lynch

Nominee for National President of the Society

BORN in Harrison County, West Virginia, in 1867, of pure American descent. Spent his boyhood on a farm learning how to make things grow. Attended a district country school where at times as many as sixty scholars were accommodated in one large room. Took preparatory work at the Academy of Buckhannon, W. Va., and from there went to West Virginia University at Morgantown, W. Va., graduating in 1891 with the degree of C. E.

In order to procure funds to meet the expenses at the University, all vacations, week ends, any many evenings, were devoted to remunerative employment, such as surveying and making a plot of Morgantown, W. Va., surveying in the oil and gas fields, laying out a railroad location through Fairmont, W. Va., and spending one summer on the maintenance of way, Maryland Division, Pennsylvania Railroad Company.

After graduation, joined the contracting and inspecting engineering firm of G. W. G. Ferris & Company, with offices at Pittsburgh, Chicago,

Tillman Davis Lynch
Nominee for National President of the Society.

and New York. From 1891 to 1897 on inspection at mill, foundry, shop and field erection, and the last two years in charge of the Chicago office.

With the United States Navy, Bureau of Steam Engineering, 1897 to 1899, covering the period of the Spanish War,—on inspection work at foundry and mill, armor plate, structural materials, boiler tubes, ferrous and non-ferrous castings, including the manufacture and treatment of hull and engine steel castings.

With the Westinghouse Electric and Manufacturing Company 1899 to date—on the general subject of materials, treatments and their applications, including such sub-divisions as inspector of materials, engineer of tests, section engineer in charge of manufacturing processes, materials specifications, metallurgical engineering on both ferrous and non-ferrous metals, materials in design and the application of research work to commercial use.

Member of the American Society for Testing Materials, active on ten of its main committees and eight additional sub-committees, covering steel, iron, non-ferrous alloys, standardizing of tests, heat treatment, effects of phosphorus and sulphur on steel, and corrosion of steel.

Member of the Engineering Society of Western Pennsylvania.

Member of the American Society for Steel Treating. Was vice president during the first year of this Society's organization and active in formulating policies of the Society. Chairman of its standards committee since its organization and active in the affairs of the Pittsburgh Chapter.

Several technical papers have been presented to the following societies and to the press:

1908—Vol. VIII,—American Society for Testing Materials.
"The Use of the Extensometer in Commercial Work."

1910—Vol. XXVI,—Engineering Society of Western Pennsylvania.
"Material Economics."

1913—Vol. XIII,—American Society for Testing Materials.
"A Study of Bearing Metals and Methods of Testing."

1915—Vol. XV,—American Society for Testing Materials.
"Elastic Limit."

1916—Vol. XVI,—American Society for Testing Materials.
"Relation Between Yield Point and Proportional Limit."

1916—Electric Journal—"Bakelite Micarta—Gears and Pinions."

1919—Electric Journal—"Manufacture of High Explosive Shells."

1919—(American Society for Steel Treating)
(Engineering Society of Western Pennsylvania)
"Notes on Heat Treatment of Steel."

1919—American Institute of Mining and Metallurgical Engineers,
"Cooling Properties of Technical Liquids."

1920—Iron and Steel Electrical Engineers.
"Babbits and Babbitting."

1921—American Society for Steel Treating, Indianapolis Convention.
"Tests Showing the Effect of High Temperatures on Malleable Iron."

1922—Chairman of Symposium Committee on "Impact Testing," American Society for Testing Materials for the convention to be held at Atlantic City, June, 1922.

W. S. Bidle

Nominated Second Vice President of the Society

Born Cleveland, Ohio, June 26, 1872. Graduate of Cleveland Public Schools.

Graduated from Case School of Applied Science in 1893, receiving degree of B. S. In 1898 received degree of M. A. from same college. Member of Sigma Xi and Tau Beta Pi fraternities.

From 1896 to 1912 was manager turn-buckle department of Cleveland City Forge & Iron Company. From 1913 to date, President of W. S. Bidle Company, Commercial Steel Treating, Cold Drawing and Turning.

W. S. Bidle
Nominee for Second Vice President of the Society

W. H. Eisenman
Nominee for National Secretary of the Society

W. H. Eisenman

Renominated National Secretary of the Society

Graduate of Kenyon College, degree Ph. B. Two years post graduate work at Leland Stanford, Jr. University, specializing in law and sciences, receiving an M. A. degree for special research work in chemistry. In addition completed post-graduate study at Morningside College and Ohio State University.

Was successively principal of high school; instructor chemistry Racine College; head of chemistry department of large high school and superintendent of schools.

Finally and at present National Secretary of the American Society for Steel Treating.

Samuel M. Havens

Nominated National Director for two years.

Graduated from the University of Rochester with the degree of A. B., and three years later from the law school of Columbia University with the degree of L.L.B.

Practiced law in New York City for five years, after which he moved to Rochester, N. Y., where he practiced for 10 years. During that time he was a member successively of the two leading law firms of that city. During this time Mr. Havens gave his attention primarily to corporations and earned an enviable reputation as a successful corporation attorney.

Mr. Havens has been as successful in business as in the legal profession. In 1917 he became secretary of the Ingalls-Shepard Forging Company of Harvey, Illinois and continued in that capacity until 1920 when he was made Assistant Treasurer and Manager of the Ingalls-Shepard Division, Wyman Gordon Company, in which position he has continued.

S. M. Havens

Nominee for National Director of the Society

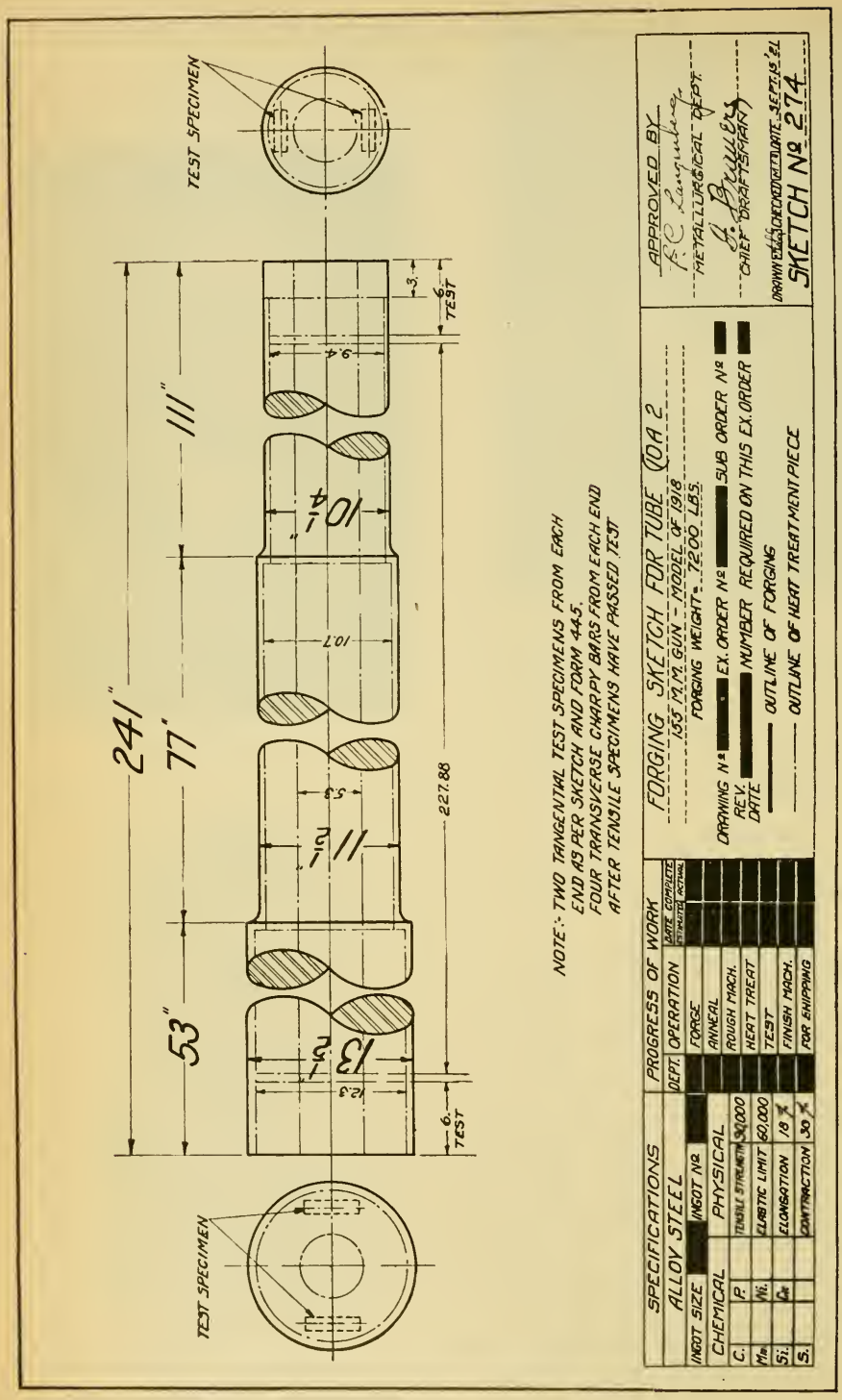


Fig. 1—A typical forging sketch giving the specifications required as well as the character and location of test specimens

PLANNING AND ROUTING OF FORGING AND HEAT TREATMENT WORK AT WATERTOWN ARSENAL

By F. C. Langenberg

AS THE Watertown Arsenal, both in war time and under normal conditions, is called upon to produce a great variety of forgings, having widely different physical characteristics, it has been necessary to evolve a very close system of control.

Since the signing of the armistice, considerable development work has been done at Watertown Arsenal, including the production of gun forgings having high physical properties, and also several experimental gun mounts. Such construction of experimental material means, in general, that only one forging or casting of a particular type is necessary. If all operations are not very carefully planned, rejections under such conditions will be exceedingly high. Therefore, the author will attempt to outline the method in vogue at Watertown Arsenal for the planning and routing of forging and heat treatment work.

The metallurgical division of the Watertown Arsenal reports directly to the commanding officer, the laboratories of the arsenal coming under the control of the metallurgical division. In order to illustrate the planning system, a 155-millimeter gun tube forging has been selected as a typical example.

Assuming that an order has been received for this forging, the engineering division issues, in addition to the regular drawings, a forging sketch, Fig. 1, which gives the specifications required, as well as the character of the test specimens and location of same. On this forging sketch, the heavy lines indicate the forging dimensions, whereas the light lines indicate the heat treatment dimensions or, in other words, the dimensions to which the tube is to be machined prior to heat treatment. The physical properties desired are shown in the column at the left of the drawing, and in cases where the production has been standardized, the chemical composition is also shown. Other shop information is placed on the forging sketch, such as the drawing and expenditure order number, as well as the sub-order applying to the particular job in question.

As in some cases the forging cannot be heat treated when rough machined in accordance with the rough machine drawings issued by the ordnance department without serious danger of cracking, the forging sketch will, as indicated above, show the heat treatment size or, in other words, the dimensions to which the piece is to be machined prior to heat treatment. It is the function of the metallurgical division to furnish to the engineering division the necessary information regarding test specimens, dimensions, etc., so that it can issue the forging sketch containing the necessary information.

After the necessary drawings and expenditure orders have been issued by the engineering division, it is then the function of the planning division, under the works manager of the arsenal, to plan and route the work through the various shops. So that the work can be planned economically, the metallurgical division furnishes to the planning room the necessary information in regard to the size and weight of ingots which will be required in order to secure the proper reduction of area and pro-

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A paper presented at the Indianapoils Convention. The author, F. C. Langenberg, is metallurgist, Watertown Arsenal, Watertown, Mass.

per discard, and if ingots of the proper composition are not in stock, the necessary information is furnished so that the proper order can be placed with the foundry.

Very close co-operation is maintained between the metallurgical division and the foundry, and this is accomplished by calling into conference various members of the foundry personnel before final decisions are arrived at relative to any particular problem at hand. The metallurgical division maintains very careful records of the melting and pouring practice and makes, in addition, a very careful ingot inspection before shipment is made to the forge shop. When an ingot is received in the forge

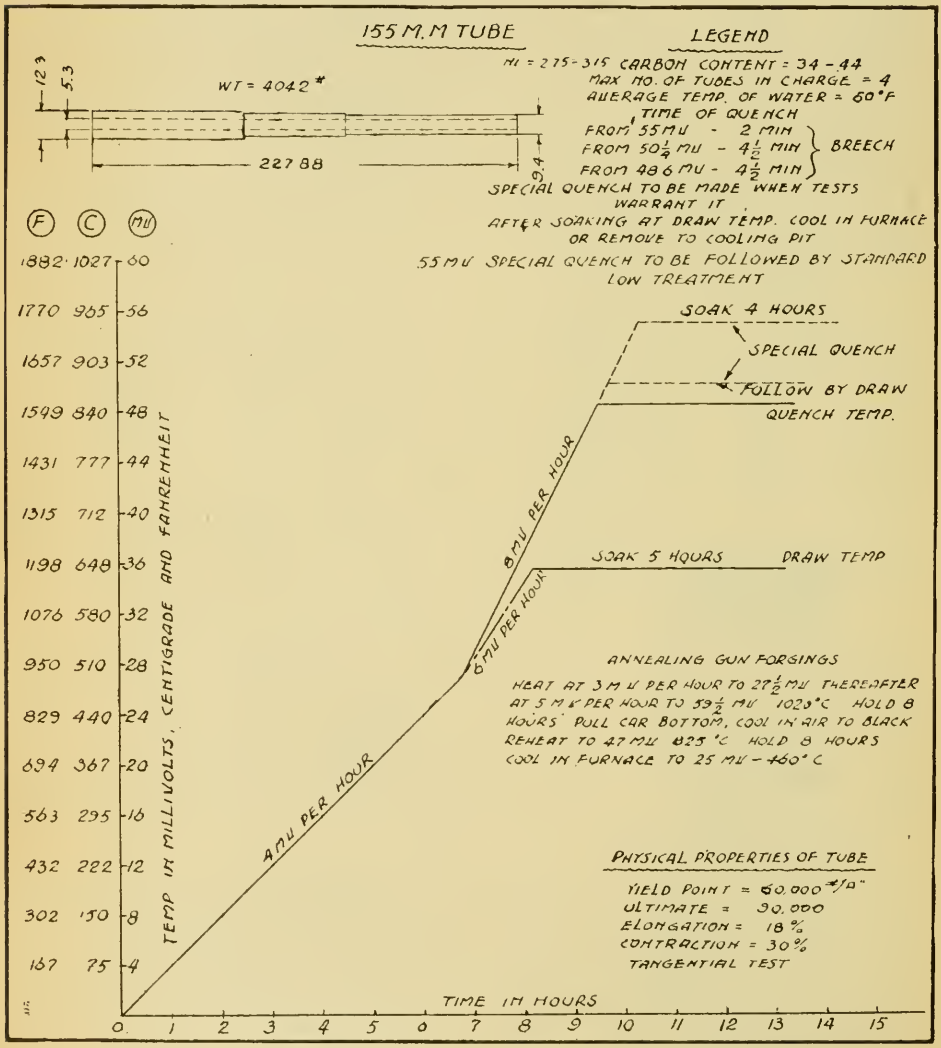

Fig. 2—Heat treatment temperature curve for gun forgings as issued to the heat treating shop

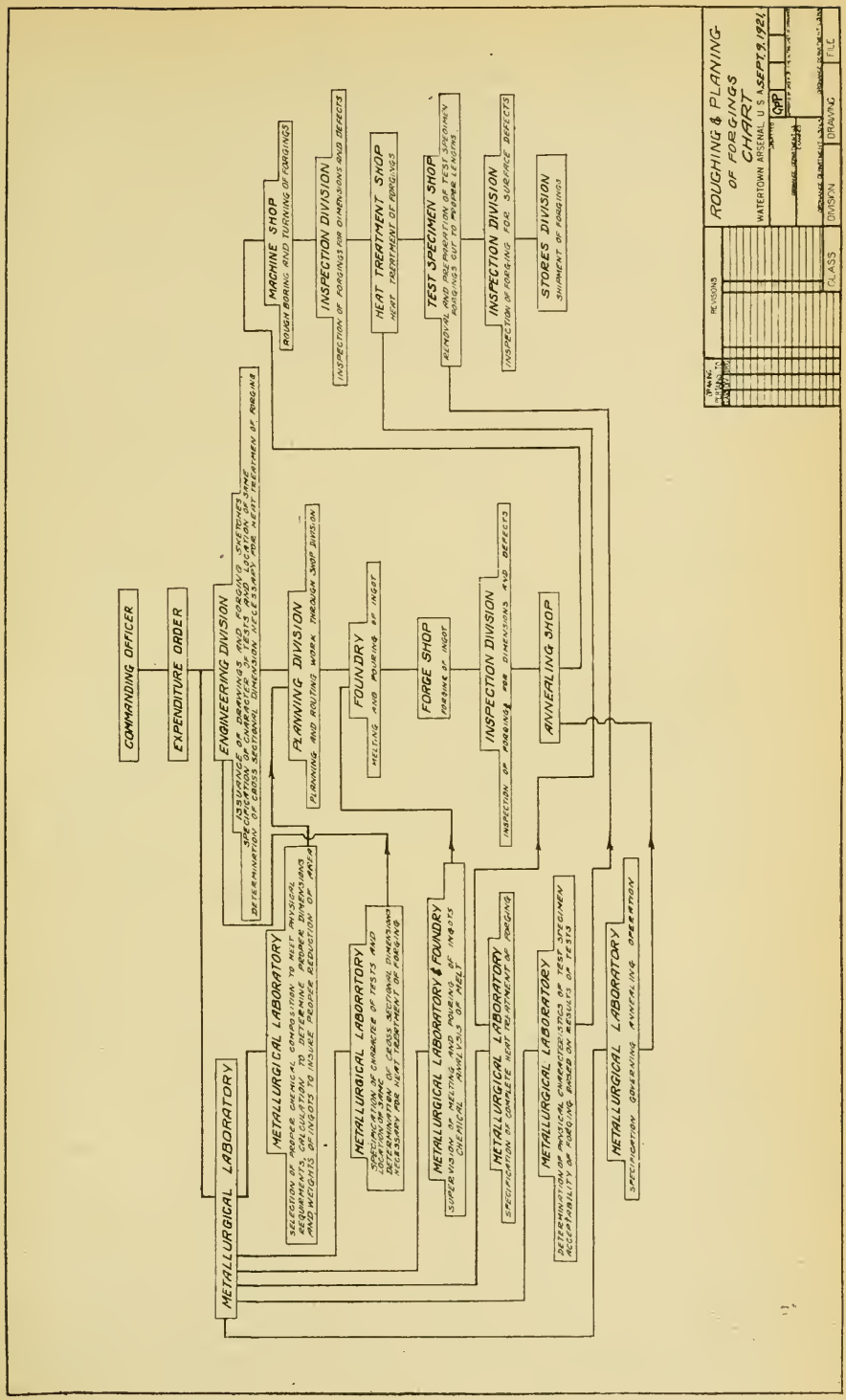

Fig. 3—Chart showing the various steps through which work must pass at the Watertown Arsenal

shop this division already has available the necessary sketches so that it can proceed without delay.

As soon as the forging is made, a very careful inspection is made by the inspection division of the arsenal, which is entirely independent of any metallurgical inspection, and this inspection covers the examination of the forging both as to dimensions and for any physical defects. Any defects are reported promptly to the metallurgical division. If the forging is satisfactory it is then shipped to the annealing shop, which shop has, prior to the receipt of the forging, received full and complete instructions as to the temperatures and times to be employed in the annealing operation.

After the annealing operation, the forging is transferred to the machine shop, where it is machined to the heat treatment dimensions. It is again inspected by the inspection division, and passed on to the heat treatment shop if the forging is satisfactory. The heat treatment shop, which has also received complete instructions as to the rate of heating, time of soaking, method of cooling, etc., then treats the forging, and after treatment removes the necessary test specimen as called for in the forging sketch, a copy of which is also in the possession of this division.

Fig. 2 shows the heat treatment instructions as they are issued to the heat treatment shop. The curve furnished gives the time of heating, as well as the time of soaking at the quenching temperature. It also gives the rate of heating and time of soaking at the drawing temperature. The curve shown also gives information regarding a special treatment which is applied when this forging fails to pass the first test. The time which the forging is to be held in the quenching medium from each quench is also furnished on this instruction chart.

The metallurgical laboratory, after carrying out the necessary physical tests, which may include impact tests as well as the standard tensile test, then makes the necessary decision as to whether the forging is satisfactory for submission to the inspector in its present condition or whether re-treatment is necessary. If re-treatment is necessary, no instructions are issued to the inspection division. If the forging is satisfactory it is passed on to the inspection division for final inspection and shipment.

The attempt has been made on the following chart, Fig. 3, to show graphically the various steps which have been described in this paper. The metallurgical laboratory, with its various functions, has been shown on the left of the drawing, and the routing of the forging to the various shops has been shown in the center and right-hand columns. The lines from the metallurgical laboratory indicate the instructions, and character of same, which are issued to the various shop divisions.

Although many objections might be found to this method of handling forging and heat treatment work, there are certain quite definite advantages which have been realized at the Watertown Arsenal.

It is a very human tendency that when any trouble occurs at the heat treatment shop the blame should be laid either to the forge shop or to the melting department; likewise, when trouble is encountered in the forge shop it is very logical that the superintendent of this shop ascribes the trouble to the melting department. When all of the operations are followed carefully by another division this tendency to pass the blame along is quite materially overcome, and the very frequent informal

conferences called by the metallurgical division have resulted in the various shop superintendents and foremen feeling that they are an essential part of any experimental program.

In the selection of the weight and cross section of a given ingot, as well as in the preparing of the forging sketch, the superintendent of the forge shop has been consulted, and as the final decision is one in which he has concurred, it is quite natural that he will make every effort to see that the job works out in a satisfactory manner.

The objection has sometimes been raised to the system employed that initiative is removed from the superintendent of a given shop who is responsible, and placed in the hands of another division. The actual working out of the system, however, does not indicate that this is the case. In the heat treating department, for instance, the superintendent is responsible for the conduct of his shop and is, furthermore, responsible that any treatment operation be carried out strictly in accordance with the instructions which he has received. If a forging fails to pass test and the treatments have been carried out as prescribed, the superintendent of the shop is not responsible for the difficulty, as the failure was due to reasons beyond his control. In other words, this system makes it quite possible to fix definitely the responsibilities of the various shop superintendents, and it has been the experience of this arsenal that all of them are in hearty accord with the system, as they know at all times what is required of them.

Discussion of Dr. Langenberg's Paper

MEMBER: Who determines the temperatures that the material is to be run at in any of the treatments that are conducted? You say the superintendent doesn't specify any particular temperatures.

DR. LANGENBERG: The temperatures are all given by the metallurgical division. Complete details are furnished by the metallurgical division, not only the temperatures, but the rates of heating, time of soaking, etc.

MEMBER: Isn't there a special chart of some kind issued by the engineering division that gives the physical properties desired or the treatment that is to be used?

DR. LANGENBERG: The physical properties are shown on the forging sketch, they are also shown on the heat treatment drawing.

MEMBER: Then it is entirely up to the metallurgical division to furnish the material according to their own ideas regarding the strength?

DR. LANGENBERG: No, this is not in our province. The designer has laid that out on the original drawings. We simply take the drawings that are furnished to us. We put down the physical properties and then we select the composition, the treatment, etc., which will, in our best judgment, get the physical properties which are needed.

MR. McINERNEY: Are any tests conducted after annealing or forging, before the pieces are sent to the shop to be machined?

DR. LANGENBERG: In a good many pieces we do conduct tests. On a number of forgings it has been necessary to determine whether our anneal is entirely satisfactory. We find that that can be accomplished by taking a test bar in the annealed state, and then make a microscopical examination from the test bar. That applies more particularly

to those forgings which require a very high physical property and which are of heavy section, where especial annealing has been given, but as a standard practice we wouldn't take tests after the annealing operation.

MR. McINERNEY: You don't follow that up as a rule, then?

DR. LANGENBERG: No, only on very special occasions do we do that.

MR. McINERNEY: Do you prescribe a separate temperature for each individual piece?

DR. LANGENBERG: The fact is that our various physical properties are met with several more or less standard compositions. We have 3.5 per cent nickel steel; in that case the temperature would be standard and only the time would be varied in accordance with the section.

MR. McINERNEY: What is it, open-hearth steel you have there?

DR. LANGENBERG: Open-hearth and electric.

PROFESSOR SAUVEUR: Have your methods resulted in any change in the quality of forgings, and in what direction?

DR. LANGENBERG: In my opinion they have resulted in securing better forgings. I think the four to one specification which was originally held to was more or less a relic than anything else, and some of the best forgings which were manufactured during the war were made with a reduction of area of 1½ to 1, and better physical results were obtained. It is very seldom that we exceed the 2 to 1 ratio at the present time. In fact, we try to keep within that. The trouble comes, however, in making a long tube; to maintain the 2 to 1 reduction in area, a very long ingot is required in relation to its diameter, which results in very serious losses in the foundry.

MR. THUM: May I ask whether you forge under a hammer or a press?

DR. LANGENBERG: All of the major forgings are made under a press; smaller breech blocks and parts of that sort are made with the hammer.

MR. THUM: What is your opinion as to the relative value of the two? Would it be safe, in other words, to reduce the forging ratio under the hammer to 1½ to 1, or 2 to 1, where it might not be safe under the press?

DR. LANGENBERG: We have never had any direct experience on that ourselves, but I know of one company that made a number of forgings, finished them under the hammer, and in that case the reduction in area was very high, much over 4 to 1, and they secured very good results. I believe they secured better results than if this same reduction had been obtained under the press.

MEMBER: I would like to ask Dr. Langenberg whether he doesn't think it is easier to meet the required physical properties, which I believe are 18 per cent elongation and 30 per cent reduction of area, with the 2 to 1 forging reduction on the ingot than it was when the specified reduction was 4 to 1? In other words, if it is not easier to meet the specification with the smaller reduction?

DR. LANGENBERG: I don't think there is any question about it. I think we can meet that specification much easier with the smaller reduction. In other words, you will come more nearly having a uniform physical property in all directions with a 2 to 1 reduction than you will with a 4 to 1, other conditions being equal.

EFFECT OF HEAT TREATMENT ON MECHANICAL PROPERTIES OF A CARBON-MOLYBDENUM AND A CHROMIUM-MOLYBDENUM STEEL

By H. J. French

WHILE the use of molybdenum as an alloying element in steels is not of recent origin, widespread attention has been given recently to the benefits derived from the addition of relatively small proportions of this element to various carbon and alloy structural steels which are generally subjected to heat treatment prior to use and usually referred to as automobile steels. More precisely, the addition of about 0.25 to 1.0 per cent of molybdenum to carbon, chromium, nickel, nickel-chromium and chromium-vanadium steels of the types widely used in automotive work is claimed to confer on the quenched and tempered alloys increased strength without material decrease in ductility. In some cases, as for example in nickel and chromium steels, this is accomplished without increasing the total proportion of alloying elements by replacing a portion of the nickel or chromium with molybdenum.

The general advantages observed, in so far as the heat treatment of molybdenum steels is concerned, have been summarized by Schmid[1] as follows:

"The outstanding features relative to the heat-treatment of molybdenum steels are the extremely wide quenching ranges available for practical heat treatment; the excellent penetrative effect of such treatment on large sizes; and the broad drawing range causing but slight modification in physical properties, this due to the retarded dissociation and reversion to normal state upon heat application after quenching."

Despite the recent publication of many data relating to the tensile properties of these alloys after different heat treatments, adequate information is lacking as to: (a) The effects of different normalizing treatments on static tensile and dynamic properties; (b) the effects of different methods of quenching and tempering on the dynamic properties; (c) the relation between the "lowering" of the transformations observed by Swinden[2] and the mechanical properties and structure. More especially are available data incomplete for commercial carbon-molybdenum steels, a study of which is essential to an understanding of the effects of small proportions of molybdenum in the heat treatment of more complex steels of the types previously indicated.

It was the purpose of this investigation to supplement the work of Swinden as regards the lowering of the transformations of a steel containing about 0.20 per cent carbon and 1 per cent molybdenum in order that a correlation with the mechanical properties of a single heat of steel might be attempted. It was likewise the intention of the author to compare different heat treatments for production of high resistance to impact and the best combinations of strength and ductility and to some extent to carry out parallel tests with a chromium-molybdenum steel.

1. M. H. Schmid: "Molybdenum Steel and Its Applications." Trans. Amer. Soc. Steel Treating, Vol. I, No. 9 (June, 1921), p. 500. Ibid: Chem. & Met. Eng., 24 (May 25, 1921), p. 927.
2. T. Swinden: "A Study of the Constitution of Carbon-Molybdenum Steels." Journ. Iron & Steel Inst., 1913, No. 5, p. 100.

A paper presented at the Indianapolis Convention. The author, H. J. French, is physicist, Bureau of Standards, Washington, D. C. Published by permission of the director, Bureau of Standards.

A complete summary of available data relating to molybdenum steels will not be attempted but there follows a resume of the work of earlier investigators of general interest or more directly connected with the factors considered in this report. Thomas Blair[3], who was among the first to study the effects of molybdenum in iron alloys, reported a case where 1 per cent of this element rendered good iron red-short. Mathews[4] found only the first of three low carbon steels containing respectively 0.95, 1.87, and 2.99 per cent molybdenum could be cogged without difficulty and this was inclined to be seamy while the last two broke and cracked under a few blows of the hammer. Guillet[5] studied the properties of mild steels containing up to 9.3 per cent molybdenum and of 0.8 per cent carbon steels containing up to 14.6 per cent of this element and reported great difficulty in working some of them. It was impossible to work steels of the first series with more than 4.5 per cent molybdenum and those of the second with more than 2 per cent.

Mathews did not ascribe his results to the presence of molybdenum but rather to the quality of the alloy used in manufacturing the steels and this was substantiated by Brearley and Ibbotson[6] who stated that "experimenters are by no means unanimous with respect to the influence

3. Thomas Blair: "Tungsten and Chromium Alloys," 1894.
4. J. A. Mathews: "A Comparative Study of Some Low Carbon Steel Alloys," Journ. Iron & Steel Inst., 1902, No. 1, p. 182.
5. Leon Guillet: "Molybdenum Steels." Rev. Met., 1904, p. 390.
6. H. Brearley and F. Ibbotson: "The Analysis of Steel Works Materials," 1920.

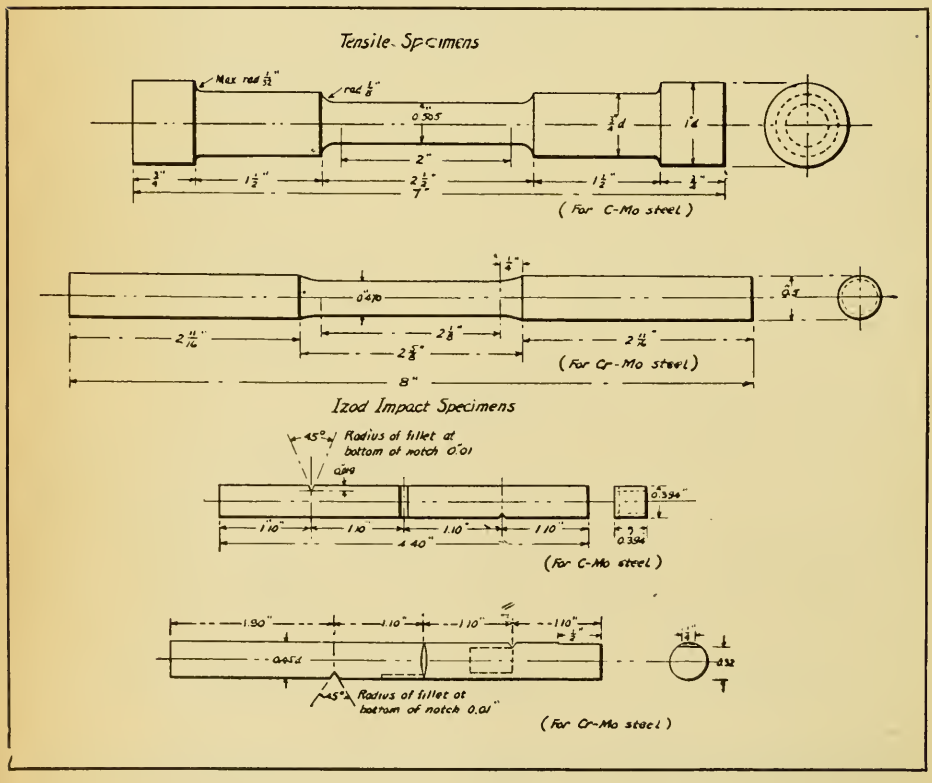

Fig. 1—Form and dimensions of test specimens used

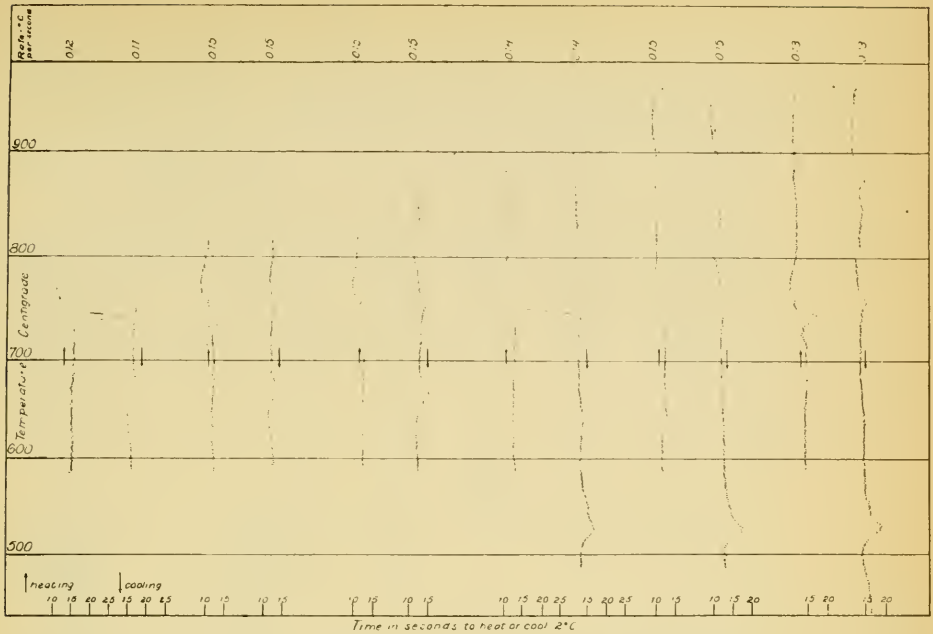

Fig. 2—Inverse-rate heating and cooling curves showing effects of maximum temperature of heating on the thermal transformations of a carbon-molybdenum steel

exerted by molybdenum on the mechanical properties of steel and according to our experience of the composition of the commercial alloys of this metal it would be surprising if they were". As more recently pointed out by Swinden[7], the proportion of sulphur and oxides in many of the powders used was sufficiently high to spoil the steel no matter how careful the melting.

Resulting from his investigation Guillet[8] classified molybdenum steels as follows:

Microstructure	Steel up to 0.20 per cent carbon	Steel up to 0.80 per cent carbon
Pearlite	0 to 2 per cent molybdenum	0 to 1 per cent molybdenum
Special constituent	Over 2 per cent molybdenum	Over 1 per cent molybdenum

The special constituent was considered by both Guillet and Portevin[9] to be double carbide. The low carbon steels with 0.50 to 1.0 per cent molybdenum showed an accentuated pearlitic structure which broke up when the proportion of this element was raised to 2 per cent while the 0.80 per cent carbon steels showed an extremely finely divided pearlite and the presence of the special constituent in increasing proportion as the molybdenum was increased above 1 per cent. Guillet also pointed out that the pearlitic steels showed excellent tensile properties with generally high yield point and good strength in torsion.

Swinden[10] carried out an elaborate series of tests on annealed, nor-

7. T. Swinden: "Carbon-Molybdenum Steels." Journ. Iron and Steel Inst., 1911, No. 3, p. 66.
8. See footnote 5.
9. A. M. Portevin: "Contribution to the Study of the Special Ternary Steels." Journ. Iron & Steel Inst., 1909, I, p. 275.
10. See footnote 7.

malized, hardened and tempered steels containing respectively 1, 2, 4, and 8 per cent molybdenum and in each series 0.20, 0.45, 0.85 and 1.15 per cent carbon. The pearlite of the annealed steels was highly emulsified and the saturation point, above which excess carbide appeared, was lowered with increase in molybdenum. No special constituent was distinguished in microscopic examination but results of carbide analysis showed more iron than necessary to account for the carbon as Fe_3C.

In later experiments Swinden[11] found that if the maximum temperature attained in heating did not exceed a certain definite value, dependent upon the proportion of molybdenum present, normal transformations were obtained in cooling regardless of the rate of heating or time at this temperature. If, however, this temperature was exceeded, the normal Ar_1 range was lowered or split and finally assumed a definite low position as the maximum temperature increased. The recovery of the normal

11. See footnote 2.

Table I
Chemical Composition of Steels Tested

Elements	Carbon-molybdenum steel, per cent	Chromium-molybdenum steel, per cent
Carbon	0.20	0.27
Manganese	0.41	1.01
Phosphorus	0.018	0.018
Sulphur	0.042	0.036
Silicon	0.22	0.20
Chromium	....	0.88
Molybdenum	0.94	0.52

Table II
Equipment Used in Determining Mechanical Properties

Test	Equipment Used
Tensile test	50,000-pound testing machine. Dial micrometers used in determining proportional limits
Impact test	120-foot-pound American made Izod type testing machine
Brinell hardness	American made Brinell hardness testing machine. 3000 kilogram load on 10 millimeter ball
Shore hardness	Recording scleroscope

Table III
Effect of Different Temperatures in Normalizing on the Mechanical Properties of a Carbon-Molybdenum Steel

Number	Heated for 30 minutes at temperature designated and air cooled, Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
A1	785	40,000	76,800	35	65.1	159	23	73—69—72
A2		37,000	76,600	36	65.8	159	25	
Average		38,500	76,700	35.5	65.4	159	24	71
A4	830	21,000	76,650	36	66.5	163	25	67—62—65
A5		22,500	76,750	35.5	68.1	159	23	
Average		21,750	76,700	35.8	67.3	161	24	65
B8	875	21,000	76,100	36	66	163	24	53—60—57
B9		25,000	76,800	35.5	66.3	163	25	
Average		23,000	76,450	35.8	66.2	163	24	57
B11	910	27,500	76,400	34.5	64.9	163	25	61—61—61
B12		31,800	76,250	32	63.1	163	24	
Average		29,650	76,325	33.2	64	163	24	61
C15	980	32,500	77,600	32	62.5	166	27	60—59—52
C16		31,500	77,000	32.5	62.8	166	26	
Average		32,000	77,300	32.2	62.6	166	26	57

Table IV

Effect of Different Quenching Temperatures on the Mechanical Properties of a Carbon-Molybdenum Steel Subsequently Quenched and Tempered at About 540 Degrees Cent. (1000 Degrees Fahr.)

Number	Held for 30 minutes at temperature designated and oil quenched. Subsequently tempered 30 minutes at 540 degrees Cent. Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
D26	785	58,000	88,650	24.5	51	179	29	
C29		57,000	88,750	24	53.5	179	30	
Average		57,500	88,700	24.2	52.3	179	30	
D25	830	70,000	104,500	20.5	51.7	207	33	48—49—47
D27		69,000	103,650	17	51	207	34	
Average		69,500	104,075	18.8	51.4	207	34	48
E37	875	74,000	104,400	21	62.5	228	37	65—65—74
E40		76,000	106,350	21	64.5	235	39	
Average		75,000	105,375	21	63	232	38	68
C28	910	78,000	110,500	23	65.5	241	38	70—68—68
C30		76,000	108,000	22.5	65.5	248	39	
Average		77,000	109,250	22.8	65.5	245	38	69
F38	980	76,000	105,250	23.5	65	235	36	67—68—67
F47		76,000	106,750	23	64.5	235	36	
Average		76,000	106,000	23.2	64.8	235	36	67

transformation was only obtained by repeated reheating to below the lowering temperature.

Based on these facts and determination of electrical resistivity, hardness, tensile properties and microstructure he concluded that "the molybdenum does not exist as double carbide and is not in solid solution in the iron but probably dispersed in the ferrite in a manner suggesting the existence of a solid colloidal solution of an iron-molybdenum compound in iron. The lowering temperature marks a change in state of the molybdenum, or iron-molybdenum compound in iron and the separation of Fe_3C is delayed until the low point temperature is reached". Swinden also found that molybdenum did not increase the Brinell hardness of annealed steels nor those quenched from 800 degrees Cent. but in samples quenched from 1200 degrees Cent., an increase in hardness was obtained which was greater the higher the molybdenum.

Arnold and Read[12] prepared a series of steels containing about 0.8 per cent carbon and from 2.4 to 20.7 per cent molybdenum and subjected annealed samples to tensile and alternating stress tests using the Arnold machine. Excessively poor results were obtained in the latter, confirming Swinden's earlier conclusion that annealing deteriorated the mechanical properties of molybdenum steels. Based on the electrolytic isolation of carbides and analysis of the carbide residue, as carried out in their study of tungsten steels[13], the authors concluded that molybdenum formed a double carbide with iron which completely replaced the cementite in the presence of about 18.25 per cent molybdenum. High proportions of this element appeared to facilitate the segregation of ferro-molybdenum-cementite in the annealed steels.

12. J. O. Arnold and A. A. Read: "The Chemical and Mechanical Relations of Iron, Molybdenum and Carbon." Proc. Inst. Mech Engs., 1915, No. 2, p. 629.
13. J. O. Arnold and A. A. Read: "The Chemical and Mechanical Relations of Iron, Tungsten, and Carbon." Proc. Inst. Mech. Engs., 1914, p. 223.

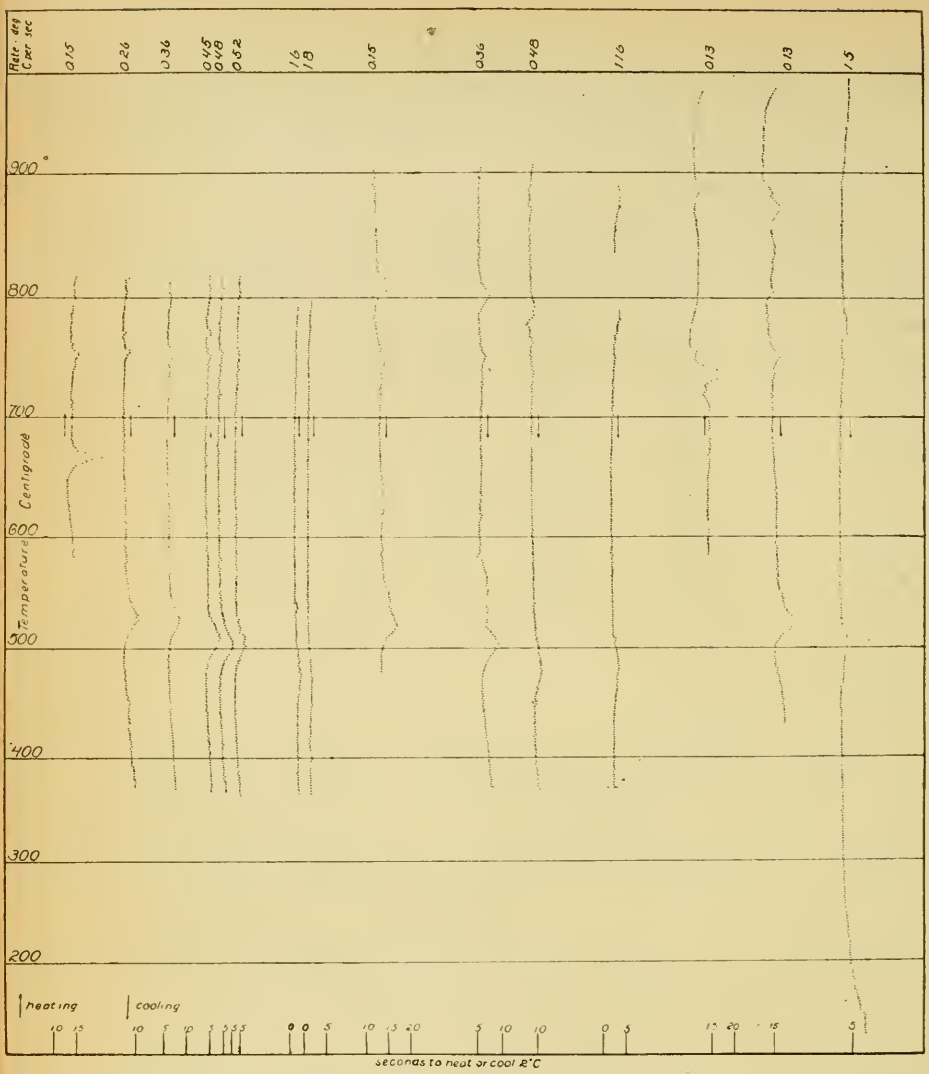

Fig. 3—Inverse-rate heating and cooling curves showing effects of different rates of temperature change in cooling from various temperatures on the transformations of a carbon-molybdenum steel

In an appendix to the work of Arnold and Read, Hadfield[14] called attention to the fact that the influence of molybdenum, per se, upon iron was small and without the presence of other elements was not likely to be of importance. In making his series of alloys containing varying proportions of carbon and molybdenum, the latter was introduced in two ways. More uniform results were obtained with the use of metallic molybdenum than with a ferroalloy, and as cast and forged the steels showed generally low elastic limits.

Recently Sargent[15] published the results of a large number of tensile

14. Sir R. A. Hadfield: "Alloys of Iron and Molybdenum." Proc. Inst. Mech. Engs., 1915, No. 2, p. 701.

15. G. W. Sargent: "Molybdenum as an Alloying Element in Structural Steels." Proc. Amer. Soc. Test. Mats., 1920.

tests obtained on different structural alloy steels. When subjected to various thermal treatments the steels containing small proportions of molybdenum, 0.25 to 1.0 per cent, showed tensile properties superior to those without. Attention was called to the very small effect on tensile properties of wide variations in hardening temperatures and to the more gradual decrease in strength of the hardened molybdenum steels with rise in tempering temperature. Generally high values were obtained for the reduction of area. The advantages obtained by adding small propor-

Table V

Mechanical Properties of a Carbon-Molybdenum Steel Quenched in Different Media from Various Temperatures With and Without Preliminary Normalizing

No.	Heat Treatment	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
G55	830°C–30 min–Oil	42,500	107,150	8	28.5	248	44	15—16—16
G56		43,000	117,250	8	31	235	43	
Average		42,750	117,200	8	29.8	242	44	16
K82	830°C–30 min–Water	51,000	176,900	8.5	24.6	321	55	20—16—12
K83		49,000	160,000	5	12	311	53	
Average		50,000	168,450	6.8	18.3	316	54	16
H57	910°C–30 min–Oil	46,500	111,250	20	52.5	235	39	57—53—59
H58		46,500	111,250	16	50	235	40	
Average		46,500	111,250	18	51.3	235	40	56
J76	910°C–30 min–Water	38,500	134,200	9	31	302	47	39—37—39
J77		37,500	132,000	10.5	31.5	286	45	
Average		38,000	133,100	9.8	31.2	294	46	38
G52	910°C–30 min–Air, then	35,000	104,230	17.5	39.2	228	33	19—20—20
G53	830°C–30 min–Oil	37,000	106,500	17.5	35.5	228	36	
Average		36,000	105,360	17.5	37.9	228	34	20
K79	910°C–30 min–Air, then	46,500	154,350	8.5	34.5	302	52	11—22—29
K80	830°C–30 min–Water	41,000	135,700	9.5	42.2	277	48	
Average		43,750	145,025	9	38.4	290	50	21

Table VI

Hardness of a Carbon-Molybdenum Steel Cooled at Different Rates from Various Temperatures to Produce the Normal or Lowered Ar_1 Transformation*

Sample Number	Maximum Temperature of Heating, Degrees Cent.	Rate of Cooling, Degrees Cent. per Second	Hardness Shore	Hardness Rockwell	Ar_1 (lowered or normal)	Transformations observed above Ar_3, Degrees Cent.
A131–1	788	0.15	26	44	Normal	...
A131–2	870	0.15	24	45	Normal	...
A131–3	912	0.15	22	47	Low	865
A131	978	0.13	24	44	Low	875
A131–A	835	0.26	24	48	Low	...
A131–C	841	0.36	24	47	Low	...
A131–B	837	0.45	24	48	Low	...
A131–D	839	0.48	26	49	Low	...
A131–E	835	0.51	25	49	Low	...
A131–K	804	1.53	26	49	Low	...
A131–L	819	1.80	25	47	Low	...
A131–3	912	0.15	22	47	Low	865
A131–F	928	0.36	24	47	Low	...
A131–G	923	0.48	25	50	Low	...
A131–H	910	0.48	24	50	Low	...
A131–J	925	1.16	25	47	Low	...

*Samples are those for which heating and cooling curves are given in Figs. 7, 8 and 9. They were heated and cooled in vacuum.

tions of molybdenum to structural carbon and alloy steels, emphasized by Sargent, have in general been substantiated in recent publications by McKnight[16], Schmid[17], and Hunter[18].

The steel tested was obtained from the Carbon Steel Co., Pittsburgh, through the courtesy of the Climax Molybdenum Co., New York. The results obtained from analysis of the bars which were received in the form of 1-inch or ½-inch chromium molybdenum hot rolled rounds, are given in Table I.

All bars were first cut into suitable lengths for triple notch Izod impact and tensile test specimens. These blanks were roughly machined to slightly greater than the required size for test specimens, as shown in Fig. 1, heat treated, finish machined and tested. All treatments were carried out in electric resistance furnaces except when tempering at 230 degrees Cent. in which case an oil bath was used. Temperatures were obtained by a 22-gage base metal thermocouple connected to a potentiometer. Tensile and impact specimens were heat treated simultaneously and for hardening were brought up to temperature with the furnace, while in tempering the sample was introduced in the heating unit at about 50 degrees Cent. (90 degrees Fahr.) below the desired temperatures. Mechanical tests of the heat treated metal were made with the instruments and under conditions given in Table II. Thermal transformations were determined by the inverse rate method[19] which has already been described in detail by Scott and Freeman[20].

In Fig. 2 are given heating and cooling curves obtained at a rate of temperature change approximating 0.15 degrees Cent. (0.27 degrees Fahr.) per second for samples heated to different temperatures between about 790 and 980 degrees Cent. (1450 and 1800 degrees Fahr.) and it will be noted that in all curves the A2 transformation is clearly shown at about 760 degrees Cent. (1400 degrees Fahr.). When cooling from about 870 degrees Cent. (1600 degrees Fahr.), thermal transformations are found like those observed in plain carbon steels of similar carbon content but when the initial temperature T_{max} is raised about 40 degrees Cent. (70 degrees Fahr.) to 910 degrees Cent. (1670 degrees Fahr.) Ar is lowered about 135 degrees Cent. (245 degrees Fahr.) from 660 to 525 degrees Cent. (1220 to 975 degrees Fahr.). With further rise in the maximum temperature of heating the position of the "low point" remains practically unchanged.

These results as regards the lowering or splitting of Ar_1 agree closely with those obtained by Swinden[21] for steel of similar composition. However, an additional transformation, in the neighborhood of 860 degrees Cent. (1580 degrees Fahr.) is observed in curves obtained by the present author when the steel is cooled from 960 degrees Cent. (1760 degrees Fahr.) or a temperature above.

Lowering of Ar_1 is not produced, when cooling at about 0.15 degrees Cent. (0.27 degrees Fahr.) per second, until an initial temperature

16. C. McKnight, Jr.: "A Discussion of Molybdenum Steels." Trans. Amer. Soc. Steel Treating, Vol. I, No. 6 (March, 1921), p. 288.
17. See footnote 1.
18. A. H. Hunter: "Physical Properties of Molybdenum Steel." Chem. & Met. Eng., 25 (July 6, 1921), p. 21.
19. The author is indebted to the Misses I. Wymore, assistant chemist and M. Preble, laboratory aid, for the heating and cooling curves shown in this report.
20. Bureau of Standards Scientific Paper 348.
21. See footnote 2.

Table VII

Mechanical Properties of a Carbon-Molybdenum Steel Tempered at Various Temperatures After Hardening in Different Ways

Number	Held for 30 minutes at temperatures designated and air cooled, Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
Steel Heated 30 Minutes at 830 Degrees Cent. and Oil Quenched								
G55	...	42,500	117,150	8	28.5	248	44	15—16—16
G56		43,000	117,250	8	31	235	43	
Average		42,750	117,200	8	29.8	242	44	16
E39	230	32,000	117,750	12	34.5	228	38	26—28—28
C23		27,000	112,250	13	37	228	38	
Average		29,500	115,000	12.5	35.8	228	38	27
H59	400	67,500	104,850	19.5	54.5	215	35	44—44—42
G51		68,000	104,850	21.5	54.5	215	35	
Average		67,750	104,850	20.5	54.5	215	35	43
D25	538	70,000	104,500	20.5	51.7	207	33	48—49—47
D27		69,000	103,650	17	51	207	34	
Average		69,500	104,075	18.8	51.4	207	34	48
Steel Heated 30 Minutes at 830 Degrees Cent. and Water Quenched								
K82	...	51,000	176,900	8.5	24.6	321	55	20—16—12
K83		49,000	160,000	5	12	311	53	
Average		50,000	168,450	6.8	18.3	316	54	16
F45	400	80,000	141,100	13.5	46.5	266	45	23—23—24
F44		83,000	146,500	12.5	45.7	269	49	
Average		81,500	143,800	13	46.1	268	47	23
C18	538	99,000	129,850	17	51.5	248	42	36—37—38
C24		100,000	131,500	17.5	49	255	45	
Average		99,500	130,675	17.2	50.2	252	44	37
F46	675	91,000	102,750	22	63.5	207	37	76—82—77
G54		89,000	101,300	22	64	207	35	
Average		90,000	102,025	22	63.8	207	36	78
Steel Heated 30 Minutes at 910 Degrees Cent. and Oil Quenched								
H57	...	46,500	111,250	20	52.5	235	39	57—53—59
H58		46,500	111,250	16	50	235	40	
Average		46,500	111,250	18	51.3	235	40	56
J74	230	40,000	102,800	23	64	223	37	50—68—73
L85		41,000	105,000	21	61	235	38	
Average		40,500	103,900	22	62.5	229	38	64
L89	400	62,000	104,500	18.5	65	228	38	72—72—74
M94		63,000	105,500	19	63	203	35	
Average		62,500	105,000	18.8	64	216	36	73
C28	538	78,000	110,500	23	65.5	241	38	70—68—68
C30		76,000	108,000	22.5	65.5	248	39	
Average		77,000	109,250	22.8	65.5	245	38	69
Steel Heated 30 Minutes at 910 Degrees Cent. and Water Quenched								
J76	...	38,500	134,200	9	31	302	47	39—37—39
J77		37,500	132,000	10.5	31.5	286	45	
Average		38,000	133,100	9.8	31.2	294	46	38
L86	400	121,000	166,500	11	49	277	53	35—43—54
L88		126,500	171,900	11.5	50	293	56	
Average		123,750	169,200	11.2	49.5	285	54	44
H60	538	93,000	120,800	14.5	59.5	269	48	46—45—44
I70		119,000	150,600	16	53.2	277	47	
Average		106,000	135,700	15.2	56.4	273	48	45
I71	675	102,000	111,350	20	63	228	38	76—67—72
I73		104,000	113,050	20.5	61.5	241	41	
Average		103,000	112,200	20.2	62.2	235	40	72

of about 910 degrees Cent. (1670 degrees Fahr.) is reached but it is obtained from lower temperatures if more rapid cooling is used. The effects of rate of temperature change on the transformations of the steel under consideration when cooling from about 830 degrees Cent. (1525 degrees Fahr.), 910 degrees Cent. (1670 degrees Fahr.) or 980 degrees Cent. (1795 degrees Fahr.) are shown in Fig. 3, and the position of the "low point" is not lowered materially with increasing speed of cooling

Fig. 4—Structures of a carbon-molybdenum steel cooled at different rates from various temperatures. X 500. Etched with 2 per cent nitric acid in alcohol. *a*. Cooled from 788 degrees Cent. at 0.15 degrees Cent. per second. *b*. Cooled from 830 degrees Cent. at 0.15 degrees Cent. per second. *c*. Cooled from 830 degrees Cent. at 1.80 degrees Cent. per second. *d*. Cooled from 870 degrees Cent. at 0.15 degrees Cent. per second. *e*. Cooled from 912 degrees Cent. at 0.15 degrees Cent. per second. *f*. Cooled from 912 degrees Cent. at 1.16 degrees Cent. per second. *g*. Cooled from 980 degrees Cent. at 0.15 degrees Cent. per second. *h*. Cooled from 980 degrees Cent. at 1.50 degrees Cent. per second

but is gradually suppressed. The position of Ar_2 remains unchanged but Ar_3 is lowered slightly and its magnitude decreases as the rate of cooling increases. The broad high temperature transformation which occurs above and nearly merges with Ar_3 in the sample cooled from about 980 degrees Cent. (1795 degrees Fahr.) at 0.15 degrees Cent. (0.27 degrees Fahr.) per second disappears when the steel is cooled at a much faster rate.

It appears that for each initial temperature there is a critical rate of cooling which will produce lowering of Ar_1 and that the higher T_{max} the slower is the rate of temperature change required to do this. Also the position of the lowered transformation is fixed (confirming Swinden) within a comparatively narrow temperature range about 525 degrees Cent. (975 degrees Fahr.) regardless of the maximum temperature of heating or rate of cooling within the limits covered by the experiments, but it is relatively easy to suppress the lowered thermal effect entirely. While the structures obtained after cooling in the different ways shown in Figs. 2 and 3 are interesting they do not throw a great deal of light upon the character of the observed changes.

In all cases the eutectoid appears highly emulsified, as shown in Fig. 4, and not like the characteristic structure of pearlite found in slowly cooled carbon steels, a condition which has already been noted by Swinden[22], Guillet[23] and others. In those samples cooled from the highest temperatures it appears in large well defined grains as is particularly well shown in Fig. 4*g*, while when very slowly cooled from the lowest temperature, 830 degrees Cent. (1525 degrees Fahr.), it is distributed in smaller masses, the boundaries of which are not so well defined. The highly emulsified eutectoid, probably equivalent to sorbite in plain carbon steels, is rather to be expected in view of the lowered Ar_1 transformation but this type of structure is also observed in samples in which the normal transformations are obtained.

Hardness and tensile properties, excepting limit of proportionality, are not changed greatly by varying the temperature from which the steel is cooled in air as shown in Fig. 5 and Table III. However, there is a general decrease in the Izod impact value as the maximum temperature is raised from 785 to 980 degrees Cent. (1445 to 1795 degrees Fahr.). The lowest value of proportional limit is observed when cooling from 830 degrees Cent. (1525 degrees Fahr.) which is at or slightly above Ac_3 but increases with elevation of the normalizing temperature. Structures of the steel subjected to the various treatments shown in Table III are similar to those given in Fig. 4.

The effect of varying oil hardening temperatures on the mechanical properties of steel subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.) is marked as shown in Fig. 6 and Table IV. The best combinations of tensile and impact properties are obtained in those samples quenched from about 910 degrees Cent. (1670 degrees Fahr.) which is about 40 degrees Cent. (70 degrees Fahr.) above the lowest temperature at which all ferrite is held in solution, Fig. 7, and simultaneous increase in tensile strength, limit of proportionality, reduction of area and impact energy absorbed (Izod) is observed when the quenching temperature is raised from just at or above Ac_3, 830 degrees Cent. (1525

22. See footnote 2.
23. See footnote 5.

degrees Fahr.), to this temperature. Obviously the lower of these two temperatures is too close to the end of Ac_3 to permit satisfactory hardening as indicated by the free ferrite obtained even after quenching in water as shown in Fig. 8.

However, this does not explain adequately the observed changes in mechanical properties, or the brittleness of steel quenched in oil or water from 830 degrees Cent. (1525 degrees Fahr.) and not subsequently tempered as shown in Table V, nor can this be used to explain the higher ductility and resistance to impact, together with lower strength, observed

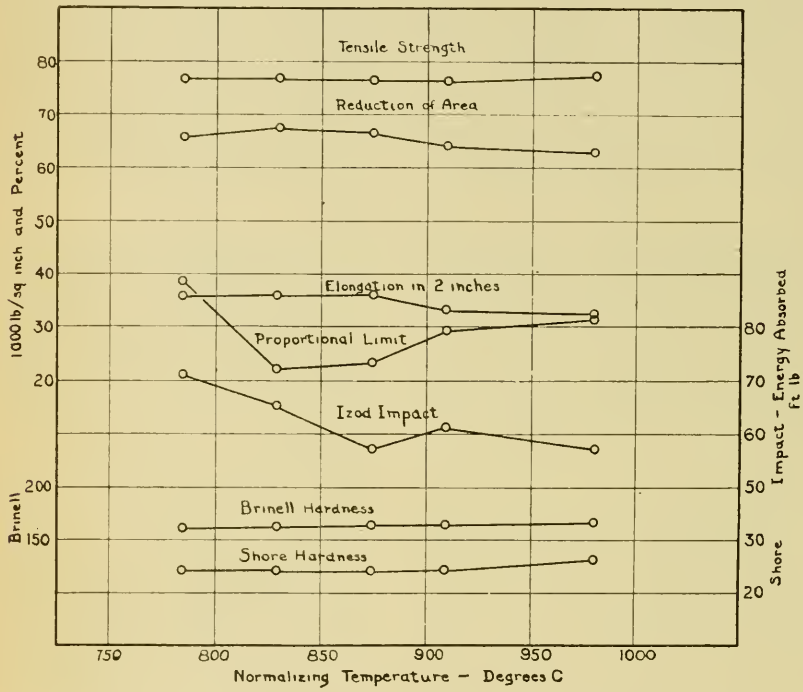

Fig. 5—Effect of different temperatures in normalizing on the mechanical properties of a carbon-molybdenum steel

in quenching in a given medium from a higher temperature, 910 degrees Cent. (1670 degrees Fahr.), for it has been shown[24] that the higher the temperature of heating within limits, the more rapidly does steel of constant mass pass through the transformations which results in a harder and more brittle product. That an increase in quenching temperature results in higher strength and lower ductility for 0.20 per cent carbon steel without molybdenum is shown by the results obtained by Roberts-Austin and Gowland[25]. The observed changes in mechanical properties of the molybdenum steel are therefore opposite to those which might, at the outset, be expected and which are obtained in carbon steel.

These changes cannot be ascribed to the lowering of Ar_1 and hence

24. C. Benedicks: "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Journ. I. & S. Inst., 1908, Vol. 2. p. 153.
25. Sir W. Roberts-Austen and W. Gowland: Sixth Report to the Alloys Research Committee. "On the Heat Treatment of Steel." Proc. Inst. Mech. Eng., 1904, Vol. I, p. 7.

a carbon change for it has been found that lowering of this transformation is produced when cooling from 830 degrees Cent. (1525 degrees Fahr.) at about 0.26 degrees Cent. (0.45 degrees Fahr.) per second which is much slower than the rate of cooling in oil or water. With higher initial temperatures the lowered Ar_1 transformation is produced at even slower rates. Also a lowering of Ar_1 would tend to harden the steel. By elimination they must therefore be ascribed, at least in part, to a molyb-

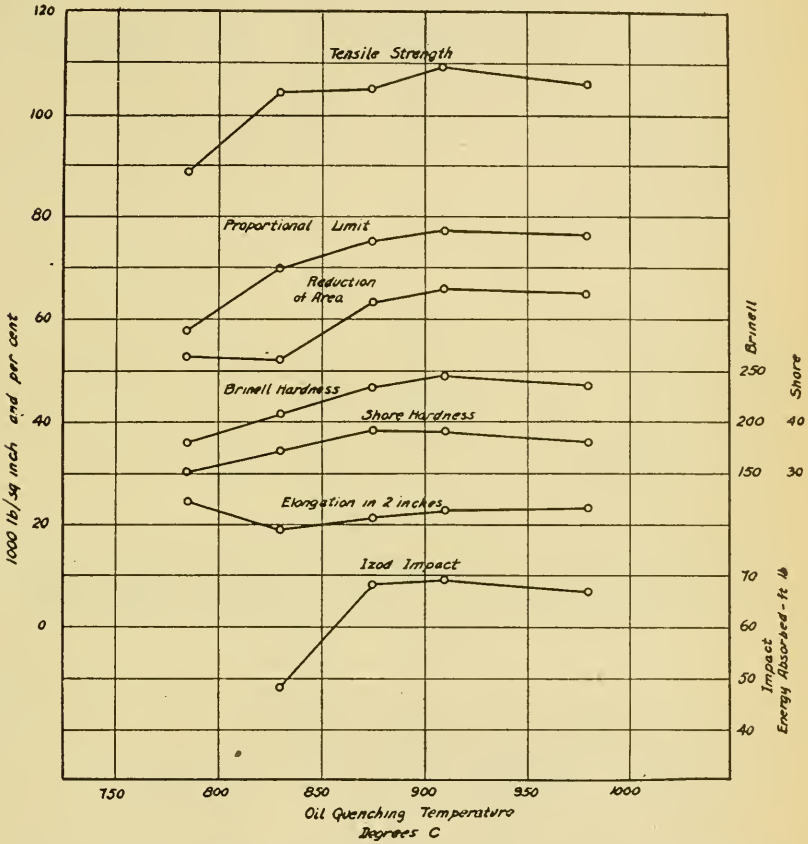

Fig. 6—Effect of different quenching temperatures on the mechanical properties of a carbon-molybdenum steel subsequently oil quenched and tempered at about 540 degrees Cent. (1000 degrees Fahr.)

denum change which under certain conditions takes place between about 830 and 870 degrees Cent (1525 and 1600 degrees Fahr.).

The nature of this change is obscure and microscopic examination does not reveal any features which might assist in an explanation. In this connection it is of interest to note that there are no recognizable variations in hardness as determined by the Shore and Rockwell methods between samples showing normal transformations and those in which the "low point" is produced, Table VI, nor are there differences between the hardness of samples in which the high temperature thermal effect is observed and those without. Probably the change is one in solid solution, in the form and distribution of an iron-molybdenum compound in iron, the condition in which molybdenum is conceived to exist by Swinden.

Table VIII

Comparison of the Mechanical Properties of a Carbon-Molybdenum Steel Heat Treated in Different Ways to Produce Definite Strengths

(Approximation)

Desired Tensile Strength, pounds per square inch	Method of Hardening	Tempering Required (30 minutes) at degrees Cent.	Proportional Limit, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
165,000	830° C–30 min–Oil	Cannot obtain desired strength						
	910° C–30 min–Oil							
	830° C–30 min–Water	(60)	55,000	8.5	22	310	53	17
	910° C–30 min–Water	420	121,000	11.5	50	283	53	44
150,000	830° C–30 min–Oil	Cannot obtain desired strength						
	910° C–30 min–Oil							
	830° C–30 min–Water	300	74,000	11.5	39	280	49	22
	910° C–30 min–Water	485	113,000	13.5	54	280	50	44
125,000	830° C–30 min–Oil	Cannot obtain desired strength						
	910° C–30 min–Oil							
	830° C–30 min–Water	565	98,000	18	52	245	43	44
	910° C–30 min–Water	610	105,000	17.5	60	255	44	58
110,000	830° C–30 min–Oil	315	49,000	16.5	45	225	36	35
	910° C–30 min–Oil	(45)	45,000	19	54	235	39	57
		540	77,000	22.5	66	245	38	69
	830° C–30 min–Water	630	93,000	20.5	59	225	39	64
	910° C–30 min–Water	685	103,000	20.5	62	235	39	73

The effects of tempering on the mechanical properties of steel hardened in different ways are shown in Figs. 9 and 10 based on data given in Table VII and will not be described in detail as the difference between samples quenched in oil or water from 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.) are fully indicated. Typical structures obtained by different treatments are shown in Fig. 11 and show the similarity, mentioned by earlier investigators, between samples quenched in a definite manner and those simlarly quenched and tempered at relatively high temperatures.

By interpolation of the graphs shown in Figs. 9 and 10 it is possible to compare different methods of treatment for the production of definite tensile strength, impact resistance, hardness or other factors. The results of such approximations for the production of definite tensile strengths and impact values, are given in Tables VIII and IX and these data show certain features of interest.

1. For the production of tensile strengths between 150,000 and 165,000 pounds per square inch higher elastic ratio and impact values and better ductility are obtained by quenching in water from 910 degrees Cent. (1670 degrees Fahr.) than from 830 degrees Cent. (1525 degrees Fahr.). Tensile strengths within the limits given, of course, cannot be developed by oil hardening. Likewise a higher tempering temperature is required to produce a given strength when quenching from the higher temperature, 910 degrees Cent. (1670 degrees Fahr.).

2. To produce a tensile strength in the neighborhood of 110,000 to 125,000 pounds per square inch water quenching from either 910 degrees Cent. (1670 degrees Fahr.) or 830 degrees Cent. (1525 degrees

Fahr.) is to be preferred as a higher elastic ratio is produced than when quenching in oil from either of these temperatures. The highest impact values are produced by quenching in water from the higher temperature, while when quenching from the same temperature in oil slightly better results are obtained than when quenching from 830 degrees Cent. (1525 degrees Fahr.) in either oil or water. Variations in ductility are not so marked when using the various methods of hardening, except when quenching in oil from 830 degrees Cent. (1525 degrees Fahr.) as when producing strengths of 150,000 to 165,000 pounds per square inch. The tempering temperatures required to produce definite strengths within the stated range, 110,000 to 125,000 pounds per square inch, decrease in the following order for the different hardening methods used: 910 degrees Cent. (1670 degrees Fahr.) water; 830 degrees Cent. (1525 degrees Fahr.) water; 910 degrees Cent. (1670 degrees Fahr.) oil; 830 degrees Cent. (1525 degrees Fahr.) oil. These treatments are likewise in the order of decreasing limits of proportionality and the lowest value obtained is less than half the highest.

3. In general, specimens quenched in water and subsequently tempered to a degree necessary to produce a definite tensile strength show higher resistance to impact than do specimens of the same tensile strength produced by oil quenching and better results are obtained when quenching from 910 degrees Cent. (1670 degrees Fahr.) in a given medium than from 830 degrees Cent. (1525 degrees Fahr.). By suitable treatment an increase of more than 100 per cent in impact values can be obtained while the strength remains practically constant. Conversely,

Table IX

Comparison of the Mechanical Properties of a Carbon-Molybdenum Steel Heat Treated in Different Ways to Produce Definite Izod Impact Values

(Approximation)

Desired Izod Impact Value, (120-foot-pound Machine Energy Absorbed) Foot-pounds	Method of Hardening or Normalizing	Tempering Required, (30 minutes) at Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore
40	830°C–30 min–Oil	375	62,000	106,000	19	51	217	35
	910°C–30 min–Oil	All impact values higher than that chosen						
	830°C–30 min–Water	550	99,000	128,000	17.5	51	250	43
	910°C–30 min–Water	150	70,000	159,000	10	38	290	49
55	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required; not included in tests made.						
	910°C–30 min–Oil	None	46,000	111,000	18	51	235	40
	830°C–30 min–Water	600	95,000	116,000	19	56	230	40
	910°C–30 min–Water	599	102,000	139,000	17	59	260	45
65	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required if possible to obtain chosen impact value; not included in tests made						
	910°C–30 min–Oil	250	43,000	104,000	21.5	63	227	38
	830°C–30 min–Water	630	93,000	109,000	20.5	59	220	38
	910°C–30 min–Water	640	104,000	119,000	19	60	245	42
	830°C–30 min–Air	...	22,000	77,000	35.5	67	161	24
70	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required if possible to obtain chosen impact values; not included in tests made.						
	910°C–30 min–Oil	500	73,000	108,000	21.5	65	235	37
	830°C–30 min–Water	650	92,000	105,000	21	61	215	37
	910°C–30 min–Water	665	103,000	114,000	19.5	62	237	40

for the production of definite impact values, higher tensile strength and better combinations of limit of proportionality and ductility may be obtained.

One of the most widely recommended of the molybdenum steels

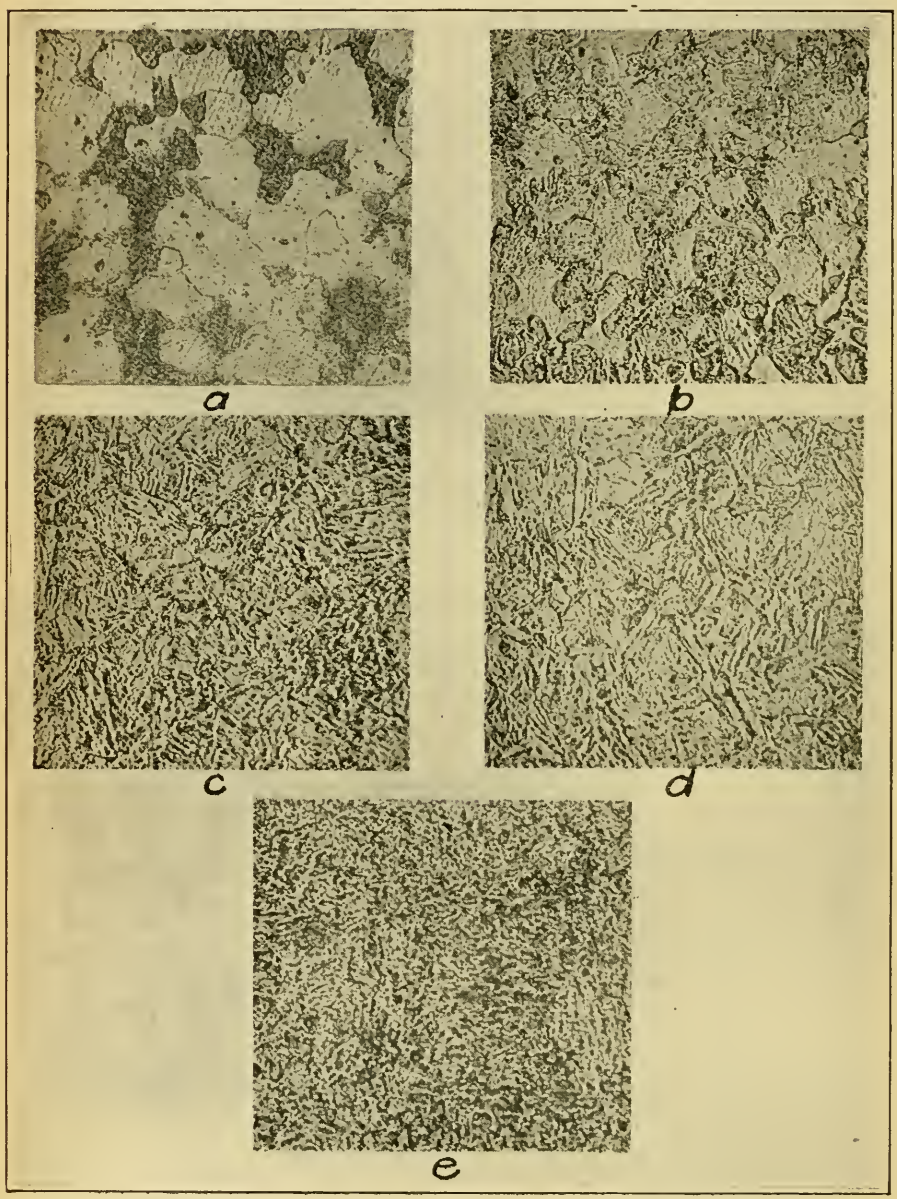

Fig. 7—Structures of a carbon-molybdenum steel oil quenched from different temperatures and subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.). X 500. Etched with 2 per cent *e*. Oil quenched from 875 degrees Cent. *d*. Oil quenched from 910 degrees Cent. *e*. Oil quenched from nitric acid in alcohol. *a*. Oil quenched from 785 degrees Cent. *b*. Oil quenched from 880 degrees Cent. 980 degrees Cent.

for structural purposes is that containing 0.8 to 1 per cent of chromium and about 0.5 per cent of molybdenum. For comparison with the carbon molybdenum steel previously considered, inverse rate heating and cooling curves were obtained on samples of the composition given in Table I. As shown in Fig. 12, one transformation is observed in heating while Ar_{3-2} and the pearlite change Ar_1 are shown in cooling. With increase in the maximum temperature of heating and a rate of temperature change of 0.15 degrees Cent. (0.27 degrees Fahr.) per second, the latter is first split in cooling from about 960 degrees Cent. (1760 degrese Fahr.). In this case, however, the upper point of the split transformation remains pronounced and occurs at the same temperature as normal Ar_1 while the "low" point is barely visible. With rise in in-

Table X

Effect of Normalizing Temperatures on the Mechanical Properties of a Chromium-Molybdenum Steel

Number	Treatment: Heated 30 minutes at temperatures designated and air cooled		Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness: Brinell	Hardness: Shore	Izod Impact (Round) foot-pound
9	730°C.	1350°F.	85,500	106,100	19	64.2	237	37	76—78—78
11			85,000	105,100	20	64.4	207	37	78—75—74
Average			85,250	105,600	19.5	64.3	222	37	76
13	790°C.	1450°F.	74,500	96,000	23	68.4	199	36	86—85—84
15			66,500	94,300	24	68.6	207	36	82—81—81
Average			70,500	95,150	23.5	68.5	203	36	83
17	815°C.	1500°F.	47,000	109,600	19	56.2	235	38	20—34
19			48,000	98,200	20	65.1	228	38	21—20
Average			47,500	103,900	19.5	60.6	232	38	24
21	845°C.	1550°F.	28,500	112,500	19.5	49.6	241	39	21—21—25
25			29,500	111,900	19.5	49.6	228	39	26—21—25
Average			29,000	112,200	19.5	49.6	235	39	23
23	870°C.	1600°F.	52,000	117,000	18.5	56	258	42	20—24—29
27			51,000	115,000	17.5	53.1	228	40	24—24—31
Average			51,500	116,050	18	54.6	243	41	25

itial temperature to about 1000 degrees Cent. (1830 degrees Fahr.) the magnitude of the low temperature thermal effect increases and that of the upper decreases but both remain in their respective positions on the temperature scale. Microphotographs of samples heated to either 960 or 1000 degrees Cent. (1760 or 1830 degrees Fahr.) and thereafter slowly cooled in a furnace to different temperatures before quenching in water to retain in large part the existing structures are shown in Fig. 13.

As quenched in water from either 960 or 1000 degrees Cent. (1760 or 1830 degrees Fahr.), the steel is martensitic and has a Brinell hardness of 477 to 495. When first slowly cooled from 960 degrees Cent. (1760 degrees Fahr.) to just below Ar_{3-2} before quenching, large grains of precipitated ferrite are found and the eutectoid exists as troostosorbite, as shown in Fig. 13*c*. The Brinell hardness of this sample (340) is very nearly the same as that which has been heated to 1000 degrees Cent. (1830 degrees Fahr.) and similarly cooled but the eutectoid in this latter case resembles martensite. When the steel is heated to 1000 degrees Cent. (1830 degrees Fahr.) and slowly cooled to a lower temperature about midway between the upper and lower points of the split Ar_1 transformation, 590 degrees Cent. (1095 degrees Fahr.),

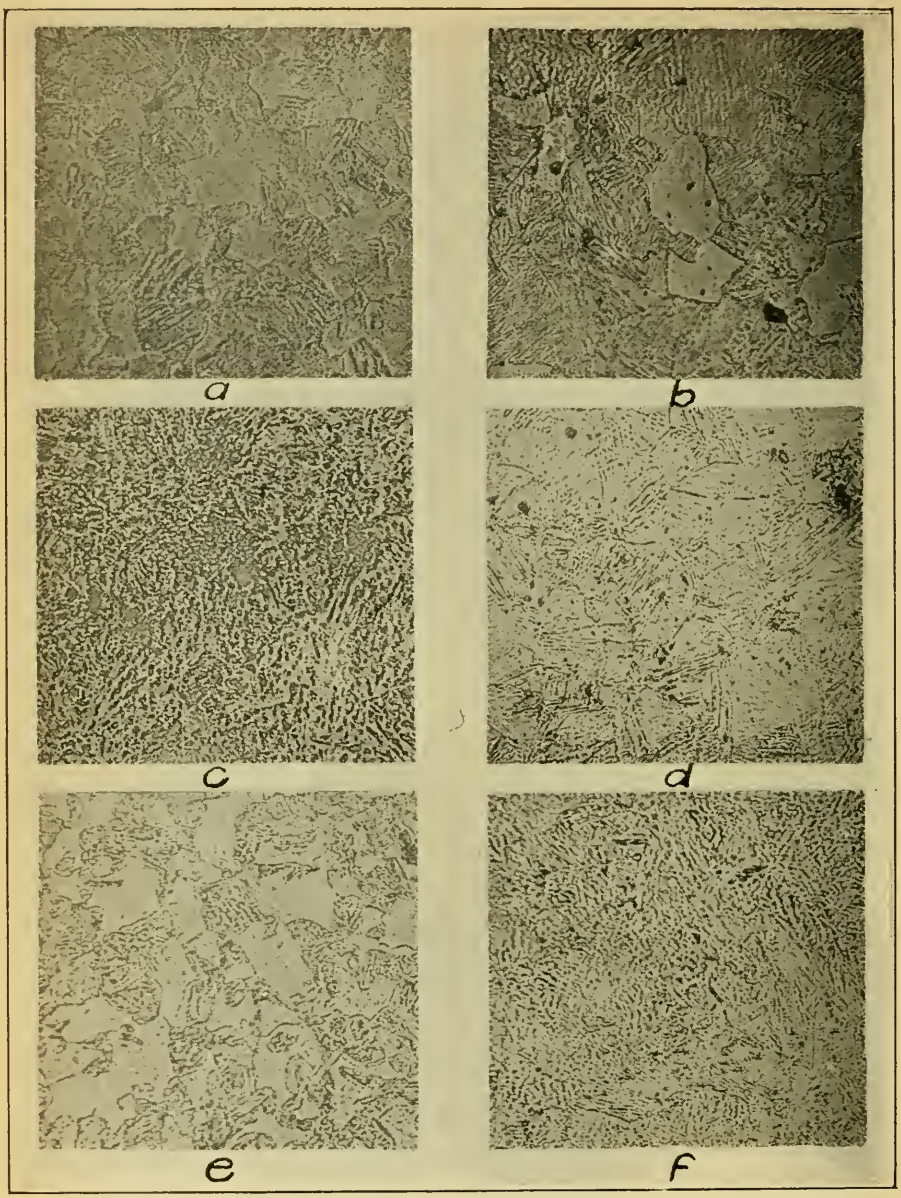

Fig. 8—Structures of a carbon-molybdenum steel quenched in different media from various temperatures with and without preliminary normalizing. X 500. Etched with 2 per cent nitric acid in alcohol. *a*. Oil quenched from 830 degrees Cent. *b*. Water quenched from 830 degrees Cent. *c*. Oil quenched from 910 degrees Cent. *d*. Water quenched from 910 degrees Cent. *e*. Air cooled from 910 degrees Cent. then oil quenched from 830 degrees Cent. *f*. Air cooled from 910 degrees Cent. then water quenched from 830 degrees Cent.

and then water quenched, the structure obtained is again troosto-sorbite but the Brinell hardness is only about 196. The structure shown in Fig. 13*c* is probably equivalent to sorbitic-pearlite as the steel has

been quenched from a temperature below the largest part of the split Ar_1 transformation and is quite soft.

Let it be assumed for the moment that Swinden's statements, to the effect that the lowering temperature "marks a change in state of the molybdenum, or iron-molybdenum compound, in iron and the separation of the carbide is delayed until the 'low' point temperature is reached," are correct. A molybdenum change might readily account for the lower hardness obtained in samples water quenched from 1000 than

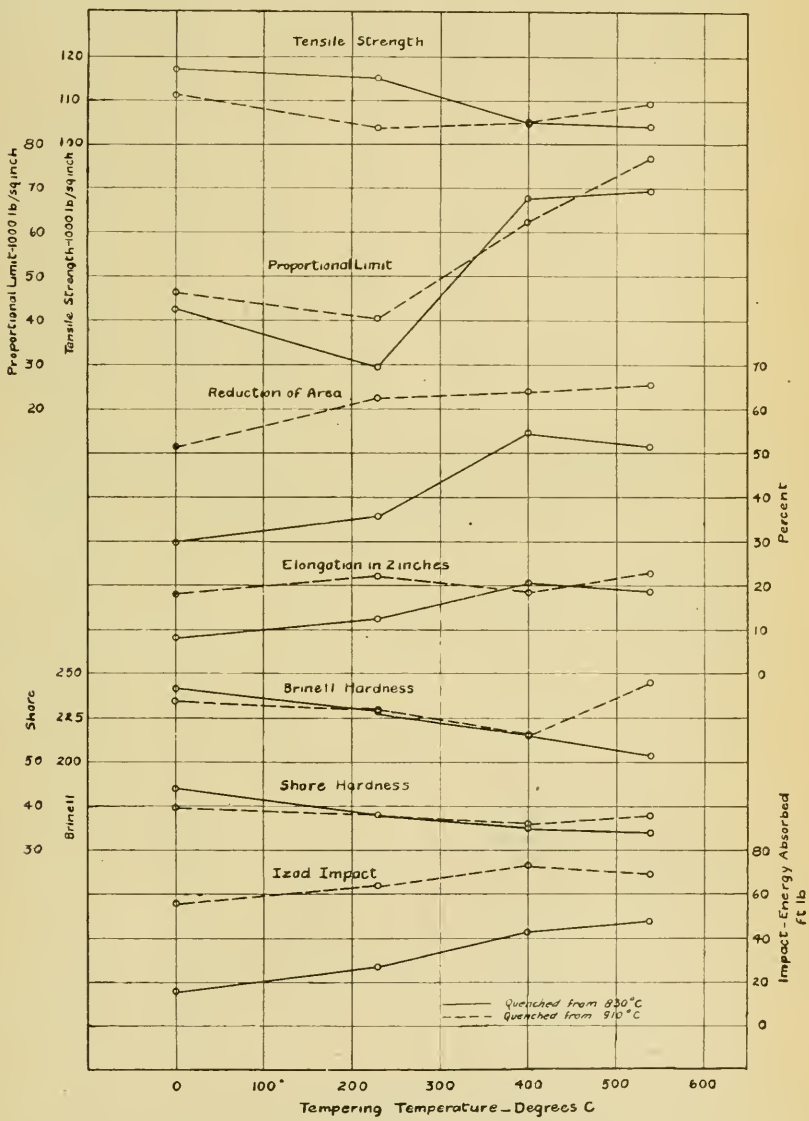

Fig. 9—Mechanical properties of a carbon-molybdenum steel tempered at various temperatures after oil quenching from either 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.)

Table XI

Effect of Different Quenching Temperatures on the Mechanical Properties of a Chromium-Molybdenum Steel Oil Quenched and Tempered at About 540 Degrees Cent. (1000 Degrees Fahr.)

Number	Treatment: Heated 30 minutes at temperatures designated and oil quenched. Tempered 30 min. at 538°C.		Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness: Brinell	Hardness: Shore	Izod Impact (Round) foot-pound
29	760°C.	1400°F.	63,500	101,200	23.5	62	226	30	80—62—60
31			66,500	103,400	23	62.6	217	32	43—49—54
Average			65,000	102,300	23.2	62.3	222	31	58
33	815°C.	1500°F.	140,000	167,900	16.5	60	332	46	43—41—43
35			125,500	158,800	15.5	58	321	51	41—45—42
Average			132,750	163,350	16	59	327	49	42
7	845°C.	1550°F.	147,000	165,500	16.5	59.1	364	56	45—45—48
37			140,000	166,800	15	58.6	364	56	43—41—47
Average			143,500	166,150	15.8	58.8	364	56	45
5	885°C.	1625°F.	136,000	163,500	16	58.3	340	55	43—40—45
39			136,000	159,000	15.5	58.3	340	53	40—38—44
Average			136,000	161,250	15.8	58.3	340	54	42
47	915°C.	1675°F.	123,000	161,200	15.5	57.2	321	52	39—46—46
41			157,000	170,200	15.5	58.6	321	50	40—41—44
Average			137,000	165,700	15.5	57.9	321	51	43
71	955°C.	1750°F.	135,000	161,000	15	59.1	302	51	38—43—43
43			134,500	161,300	14	58.1	302	49	41—44—47
Average			134,750	161,150	14.5	58.6	302	50	43

Table XII

Mechanical Properties of a Chromium-Molybdenum Steel Tempered at Various Temperatures After Quenching in Oil from 845 Degrees Cent. (1550 Degrees Fahr.)

Number	Treatment: Heated 30 minutes at 843 degrees Cent. and oil quenched. Tempered 30 minutes at temperatures designated and oil quenched		Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness: Brinell	Hardness: Shore	Izod Impact (Round) foot-pound
45	(Not tempered)		178,000	4.5	7.9	357	51	9—12—12
49			184,500	3.5	3.9	418	54	8— 9— 9
Average			181,250	4	5.9	385	53	10
51	205°C.	400°F.	187,300	6	9.5	364	63	9—12—13
53			186,700	7.5	10.8	418	58	12—13—15
Average			187,000	6.8	10.2	391	61	12
55	425°C.	800°F.	168,200	10	36.6	364	59	19—18—19
57			185,600	..	..	387	57	15—16—16
Average			176,900	10	36.6	376	58	17
59	650°C.	1200°F.	124,100	20	61.9	252	42	59—65—67
61			126,300	21.5	64	269	44	59—60—66
Average			125,200	20.8	63	261	43	63
63	705°C.	1300°F.	117,400	19	67.1	255	40	68—74—75
3			116,800	21.5	67.4	255	44	
Average			117,100	20.2	67.2	255	42	72
65	760°C.	1400°F.	100,000	22	68.7	217	36	94—95—96
1			102,700	25.5	70.5	228	34	90—95—95
Average			101,350	23.8	69.6	223	35	94

from 960 degrees Cent. (1830 and 1760 degrees Fahr.). In fact, this is the only readily recognizable cause except for the possible contributing effect of chromium. That this latter element is wholly responsible for the observed changes appears improbable in view of the relatively small

proportion contained in the steel which likewise is low in carbon. It also appears doubtful that chromium contributes very largely to these changes in view of the similarity of the effects observed in the carbon molybdenum steel.

In slowly cooling from 960 degrees Cent. (1760 degrees Fahr.) the full lowering of Ar_1 is not obtained, as shown in Fig. 12, so that the carbide separation may be considered to take place at the upper and nearly normal point, 660 degrees Cent. (1220 degrees Fahr.). In cooling slowly from 960 to 715 degrees Cent. (1760 to 1320 degrees Fahr.) before immersing in water, the quenching temperature may therefore be considered to be about 55 degrees Cent. (100 degrees Fahr.) above the carbide release and under such conditions the eutectoid appears as

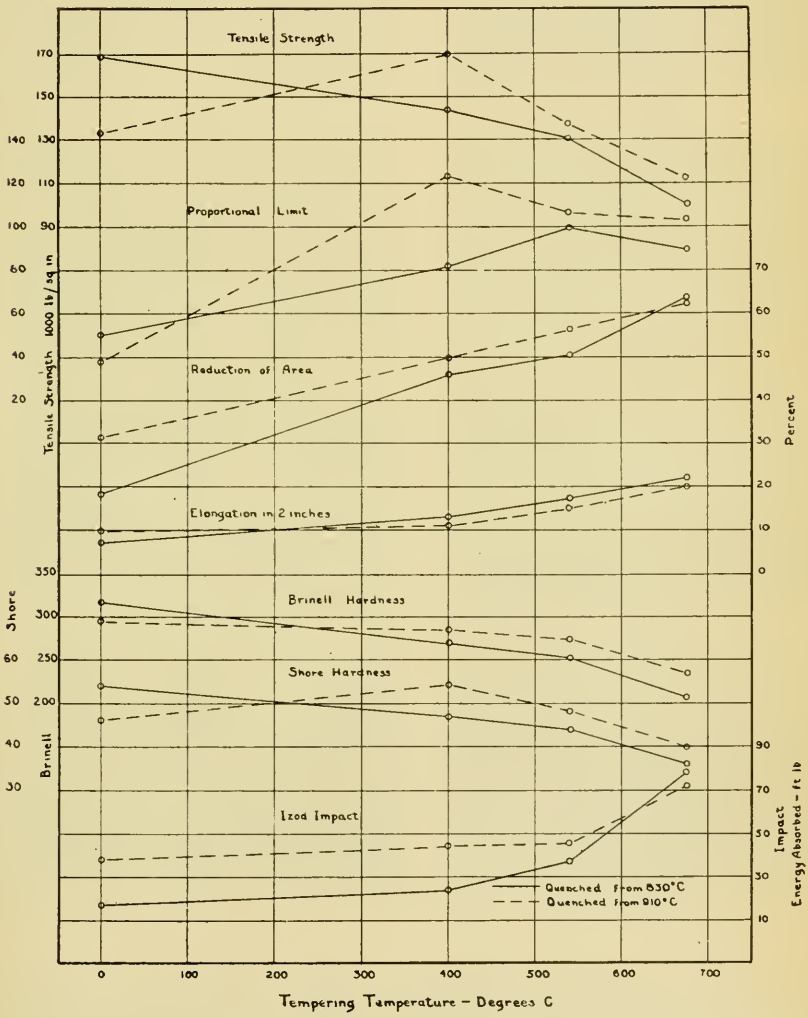

Fig. 10—Mechanical properties of a carbon-molybdenum steel tempered at various temperatures after water quenching from either 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.)

troosto-sorbite. In cooling from 1000 degrees Cent. (1830 degrees Fahr.) the normal Ar_1 has been largely lowered and a well defined thermal effect is obtained at about 480 degrees Cent. (895 degrees Fahr.). Thus when the steel is cooled to 715 degrees Cent. (1320 degrees Fahr.) before immersing in water, the range of separation of the largest part of the carbide has been exceeded by about 235 degrees

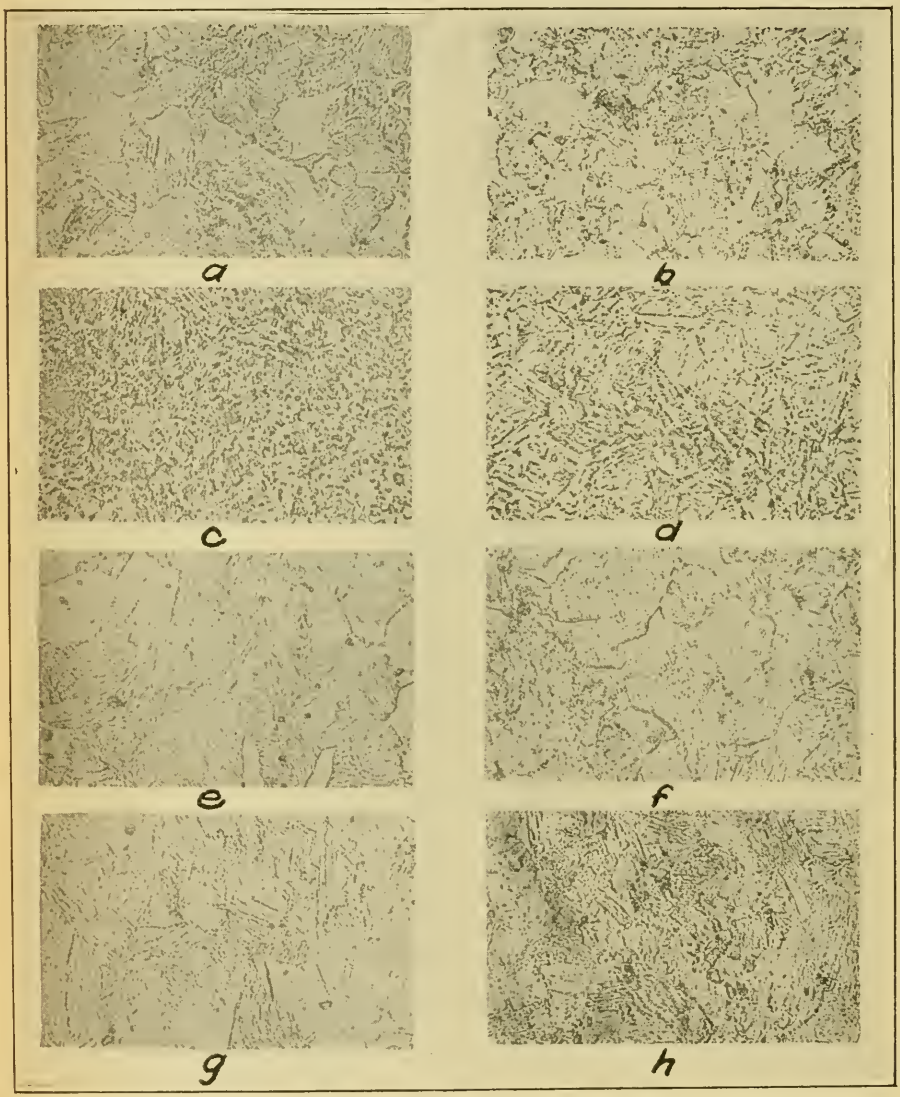

Fig. 11—Structures of a carbon-molybdenum steel oil or water quenched from 830 degrees Cent. or 910 degrees Cent. and tempered at different temperatures. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Oil quenched from 830 degrees Cent. *b.* Oil quenched from 830 degrees Cent.; tempered at 540 degrees Cent. *c.* Oil quenched from 910 degrees Cent. *d.* Oil quenched from 910 degrees Cent.; tempered at 540 degrees Cent. *e.* Water quenched from 830 degrees Cent. *f.* Water quenched from 830 degrees Cent.; tempered at 675 degrees Cent. *g.* Water quenched from 910 degrees Cent. *h.* Water quenched from 910 degrees Cent.; tempered at 675 degrees Cent.

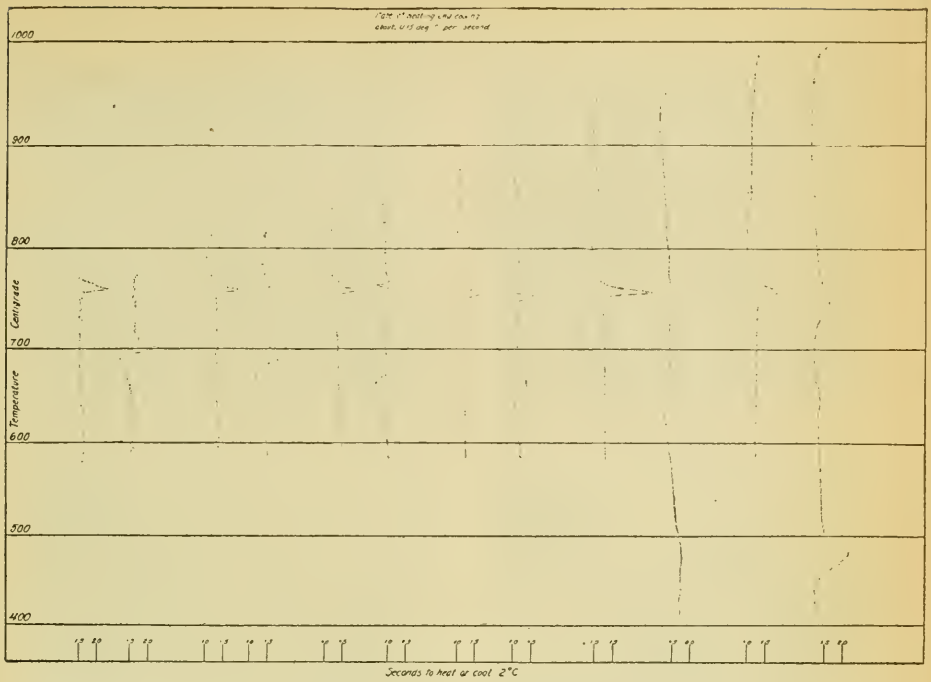

Fig. 12—Inverse-rate heating and cooling curves showing effect of maximum temperature of heating on the transformations of a chromium molybdenum steel

Cent. (345 degrees Fahr.) and martensite is produced[26]. However, on account of the assumed change in molybdenum attended by a lowered Ar_1 transformation, the hardness of the steel decreases, as shown by the samples quenched in water from 960 and 1000 degrees Cent. (1760 and 1830 degrees Fahr.), or conversely about the same hardness is obtained in the troostitic steel which has been heated to a maximum temperature of 960 degrees Cent. (1760 degrees Fahr.) as is observed in the alloy taken to 1000 degrees Cent. (1830 degrees Fahr.) which shows a less complete transition of the eutectoid to stable form.

The low Brinell hardness of the steel, when slowly cooled from 1000 to 590 degrees Cent. (1830 to 1095 degrees Fahr.) before water quenching, may be due to a combination of causes, as follows: (a) The molybdenum change previously mentioned which results in a softening of the steel; (b) the incomplete lowering of Ar_1 which begins at the upper point of the split transformation but is sufficiently retarded so that the largest part of the carbide separation takes place at the "low" point temperature. This means less carbide in solution in the quenched metal and a somewhat softer steel; (c) the suppression of the "low" point change is not as complete when quenching from a temperature only 110 degrees Cent. (200 degrees Fahr.) above this change as it is from higher temperatures.

While this line of reasoning cannot be accepted in the light of a complete explanation as it is based on assumptions which have already

26. The higher the temperature, within limits, of heating the more rapidly does steel of constant mass pass through the transformations and the more completely is the transformation prevented. See also footnote 5.

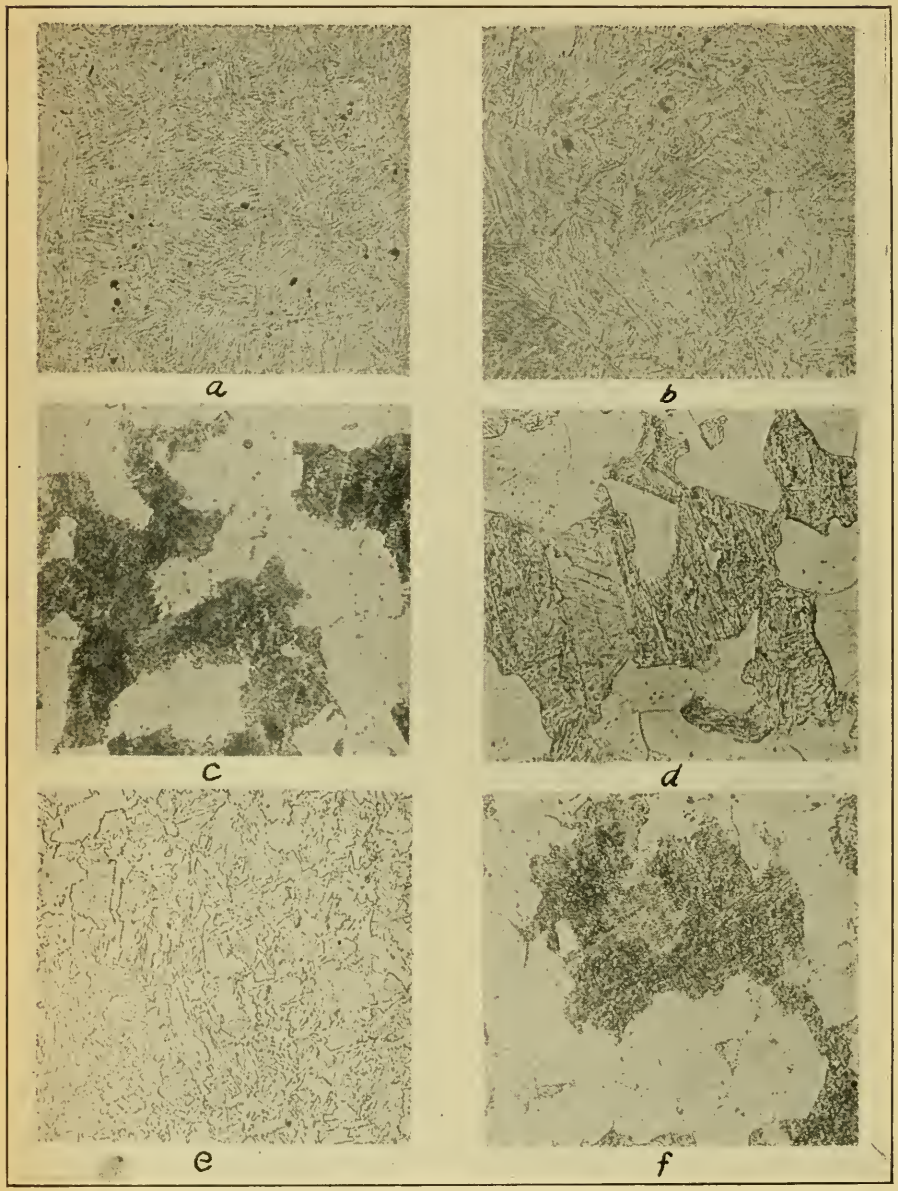

Fig. 13—Structures and hardness of a chromium-molybdenum steel heated to 960 or 1000 degrees Cent. and slowly cooled to different temperatures before water quenching. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Heated to 960 degrees Cent. and water quenched. Brinell 495. *b.* Heated to 1000 degrees Cent. and water quenched. Brinell 477. *c.* Heated to 960 degrees Cent., furnace cooled to 715 degrees Cent. and water quenched. Brinell 340. *d.* Heated to 1000 degrees Cent., furnace cooled to 715 degrees Cent. and water quenched. Brinell 321. *e.* Heated to 960 degrees Cent., furnace cooled to 590 degrees Cent. and water quenched. Brinell 196. *f.* Heated to 1000 degrees Cent., furnace cooled to 590 degrees Cent. and water quenched. Brinell 196.

been stated, it is interesting to note that the chromium-molybdenum steel shows a tendency to "soften" when high quenching temperatures are used as does the carbon-molybdenum steel considered at the beginning of this report but this change is produced at higher temperatures in the case of the chromium-molybdenum steel containing the lowest proportion of molybdenum.

A decrease in the limit of proportionality in tensile tests and lower impact values, as shown in Fig. 14 and Table X, are obtained when the temperature from which the steel is cooled in air is raised from 780 to 845 degrees Cent. (1450 to 1550 degrees Fahr.). Liebig[27] reported a

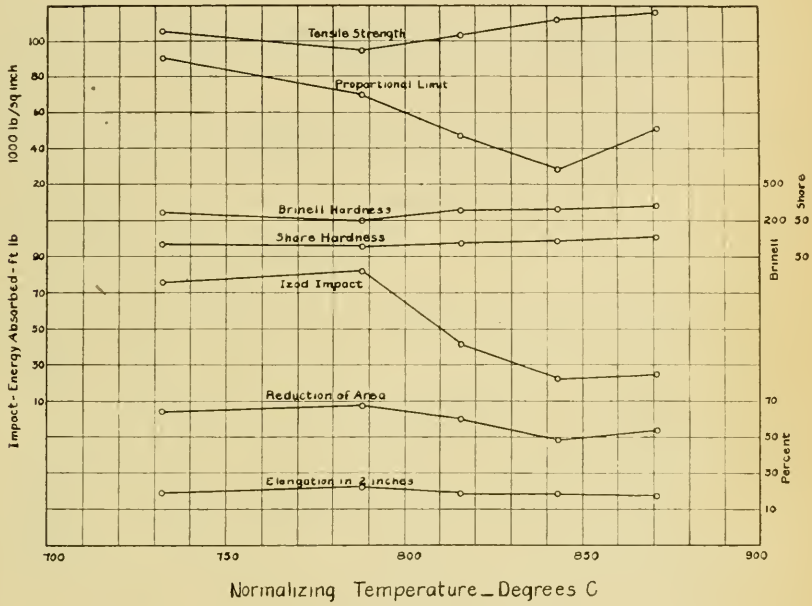

Fig. 14—Effect of varying normalizing temperatures on the mechanical properties of a chromium-molybdenum steel

similar decrease in yield point for the same type of steel containing slightly higher carbon, 0.39 per cent, when the annealing temperature was increased from 760 to 785 degrees Cent. (1400 to 1450 degrees Fahr.), whereas a carbon-chromium steel without molybdenum did not behave similarly. These changes may, as in previous instances, be explained by a molybdenum change.

In Fig. 15 and 16 and Tables XI and XII are shown respectively the effects of varying temperatures in oil hardening steel subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.) and the effects of tempering at different temperatures on the mechanical properties of the alloy first quenched in oil from 845 degrees Cent. (1550 degrees Fahr.). No extended discussion is required as these data confirm the wide quenching range in which the steel may be hardened in oil without materially altering the tensile or impact properties and the general resistance to decrease in strength of the hardened steel by tem-

27. J. O. Liebig: "A Brief Record of Results of the Annealing of a Chromium-Molybdenum and a Chromium Steel." Journ. Amer. Steel Treaters Soc., Dec., 1919, p. 168.

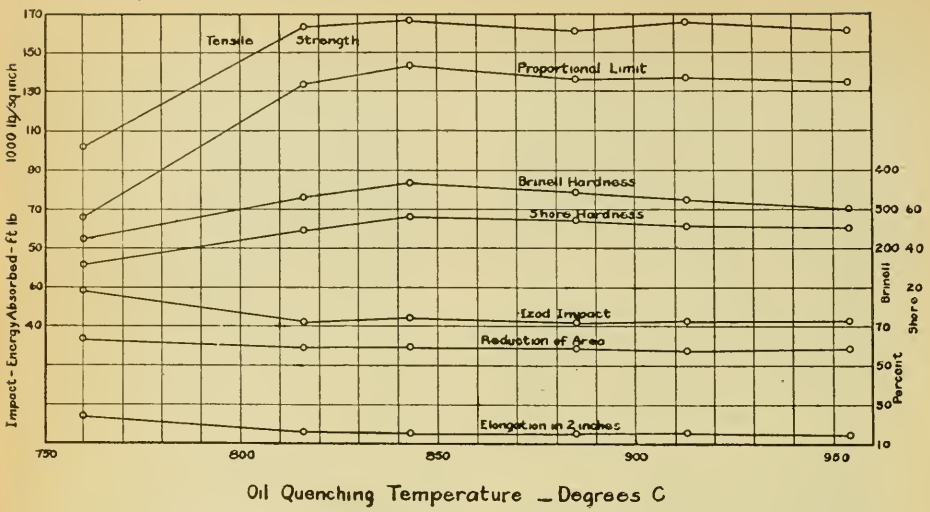

Fig. 15—Effect of different quenching temperatures on the mechanical properties of chromium-molybdenum steel subsequently oil quenched and tempered at about 540 degrees Cent. (1000 degrees Fahr.)

pering until relatively high temperatures are reached. However, when tempering at or below 430 degrees Cent. (800 degrees Fahr.) very low impact values are obtained but these increase very rapidly when the tempering temperature is raised from 430 to 650 degrees Cent. (800 to 1200 degrees Fahr.).

Microphotographs reproduced in Fig. 17 for samples subjected to various heat treatments show a finely divided and highly emulsified structure. In Fig. 17*d* and 17*e* the precipitated ferrite is distributed throughout the matrix in more irregular grains than are generally found in plain carbon steels. In fact, the lack of sharp and regular grain boundaries and the finely divided state of the matrix, especially in Fig. 17*e*, suggests a very strong and tough metal.

The important features determined by the tests previously described may be summarized as follows:

I. Steel containing 0.20 *per cent carbon and* 1 *per cent molybdenum.*

1. For each maximum temperature of heating there is a critical rate of cooling which will lower Ar_1. The higher the initial temperature the slower is the rate of cooling required to produce the lowered transformation but by whatever combination this is produced the position of the "low point" is fixed within a narrow temperature range about 525 degrees Cent. (975 degrees Fahr.). Its suppression can readily be brought about, however, by increasing the rate of cooling.

2. A high temperature transformation is observed slightly above and almost merging with Ar_3 when the steel is cooled from temperatures at or above 960 degrees Cent. (1760 degrees Fahr.) at a rate of temperature change approximating 0.15 degrees Cent. (0.27 degrees Fahr.) per second but is not observed when cooling at much faster rates.

3. Ar_2 is fixed at about 760 degrees Cent. (1400 degrees Fahr.) independent of the maximum temperature of heating or rate at which the steel is cooled.

4. The most suitable temperature from which to harden the steel is in the neighborhood of 910 degrees Cent. (1670 degrees Fahr.). Free ferrite is found after quenching from 830 degrees Cent. (1525 degrees Fahr.) but the observed changes in mechanical properties with rise in quenching temperature within this range cannot be explained by known changes in carbon or iron, by differences in the rate at which the steel passes through the critical ranges resulting from changes in initial temperature of cooling, by unsatisfactory hardening or by the lowered Ar_1 transformation, except as related to a molybdenum change, for they are opposite to the changes found in plain carbon steel under similar conditions of treatment.

5. For the production of definite tensile strength, water quenching is to be preferred on account of the higher proportional limit, ductility, and impact values obtained, and conversely better tensile properties are obtained for a given impact resistance.

6. Raising the quenching temperature from 910 degrees Cent. (1670 degrees F.) to 980 degrees Cent. (1795 degrees Fahr.) does not alter materially the mechanical properties of the steel when subsequently tempered at a relatively high temperature, 540 degrees Cent. (1000 degrees Fahr.).

II. Steel containing 0.27 *per cent carbon,* 0.9 *per cent chromium and* 0.5 *per cent molybdenum.*

7. The Ar_1 transformation is first split and lowered when cooling from 960 to 1000 degrees Cent. (1760 to 1830 degrees Fahr.) at about

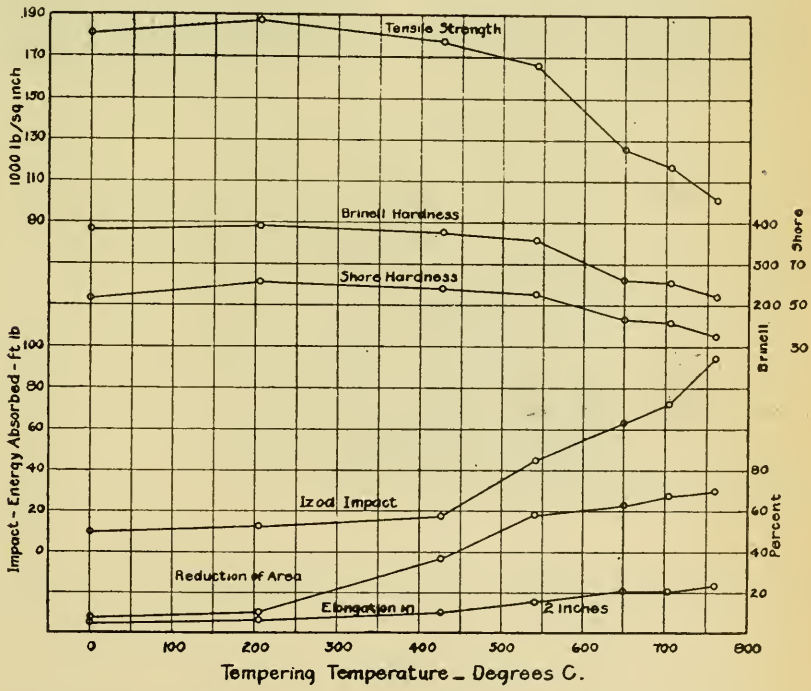

Fig. 16—Mechanical properties of a chromium-molybdenum steel tempered at various temperatures after quenching in oil from 845 degrees Cent. (1550 degrees Fahr.)

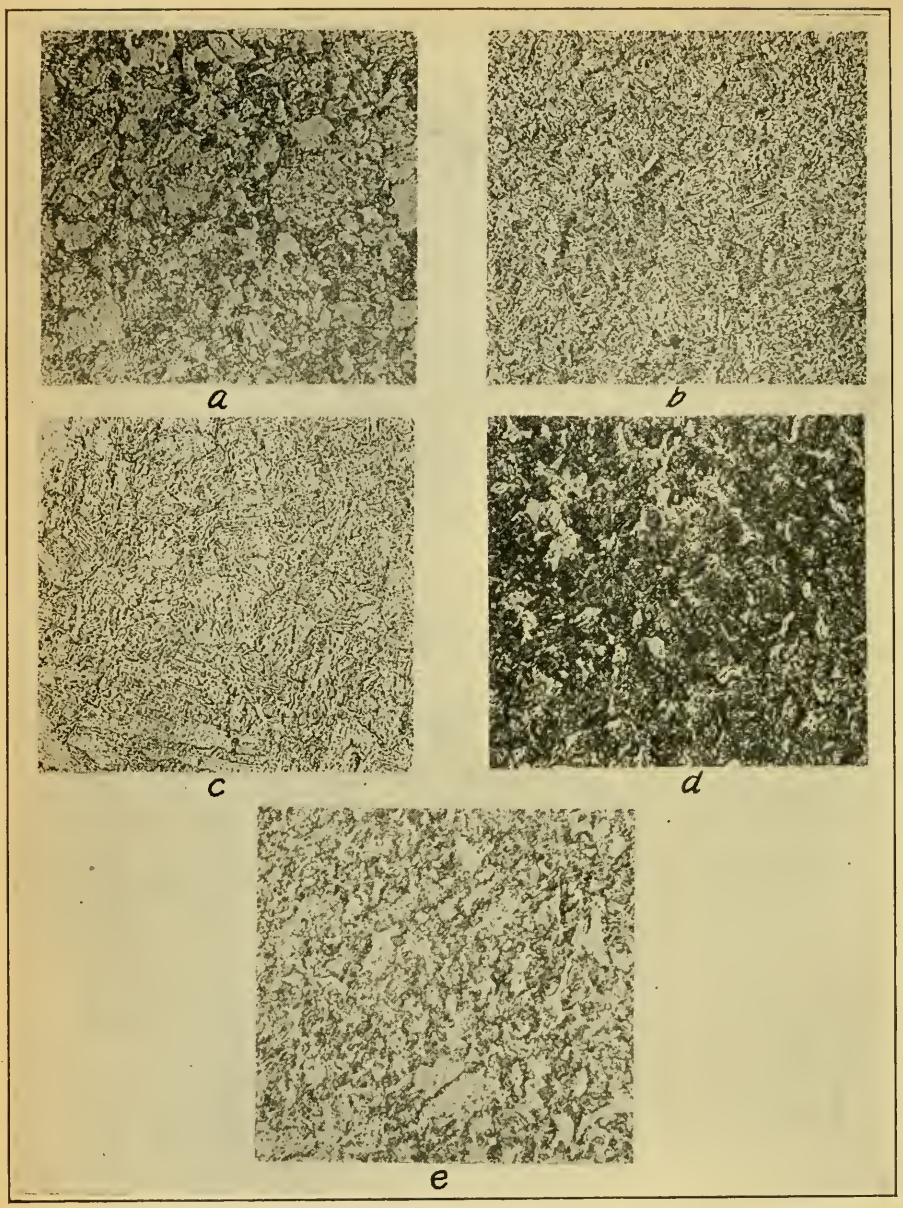

Fig. 17—Structures of a chromium-molybdenum steel heat treated in different ways. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Oil quenched from 760 degrees Cent.; tempered at 540 degrees Cent. *b.* Oil quenched from 845 degrees Cent.; tempered at 540 degrees Cent. *c.* Oil quenched from 955 degrees Cent.; tempered at 540 degrees Cent. *d.* Oil quenched from 845 degrees Cent.; not tempered. *e.* Oil quenched from 845 degrees Cent.; tempered at 650 degrees Cent.

0.15 degrees Cent. (0.27 degrees Fahr.) per second, the "low point" being observed at about 480 degrees Cent. (895 degrees Fahr.). In water quenching from the highest temperature, a lower hardness is obtained than when similarly cooling from 960 degrees Cent. (1760

degrees Fahr.). In this respect the chromium-molybdenum steel behaves similarly to steel containing 0.20 per cent carbon and 1 per cent molybdenum, except that the observed changes are produced from higher temperatures.

8. In normalizing the chromium-molybdenum steel a low limit of proportionality and impact resistance are obtained when using temperatures between about 780 to 845 degrees Cent. (1450 to 1550 degrees Fahr.).

9. The fact that no material changes in tensile or impact properties are produced by oil quenching the chromium-molybdenum steel from a wide range of temperatures when subsequently tempered at 540 degrees Cent. (1000 degrees Fahr.) has been confirmed. Likewise confirmation of the resistance of the oil hardened steel to decrease in strength by tempering has been obtained. To increase the low impact values of the hardened steel, a tempering temperature in the neighborhood of 650 degrees Cent. (1200 degrees Fahr.) is required.

Acknowledgment is made to W. G. Johnson, assistant physicist, and to T. E. Hamill, laboratory apprentice, who carried out the greater part of the routine work in connection with the described tests.

Discussion of Mr. French's Paper

MR. MERTEN: I would like to ask the speaker why he operated with a low carbon material and chrome molybdenum steel when most of that in use is around 0.40 per cent?

MR. FRENCH: When we planned a series of tests we wanted material in the neighborhood of 0.35 or 0.40 per cent carbon but the heat we obtained contained lower carbon. What we were particularly interested in was the effect of heat treatment, not so much in getting the carbon for a given molybdenum content. We were not interested primarily in comparing the molybdenum steel with other alloy steels as a good deal of information has been published along that line. What we were interested in was the treatment and the steel was put through various thermal manipulations with that in mind.

MR. JOHNSON: I would like to ask the speaker the depth of the slot in the impact specimens?

MR. FRENCH: For the carbon-molybdenum steel a square 45-degree, triple-notched Izod specimen was used having a notch depth of 0.019 inches. For the chrome-molybdenum steel a round impact specimen was employed with a similar type of notch.

MR. SCOTT: Does molybdenum alloy with ferrite or does it form carbide?

MR. FRENCH: How much molybdenum?

MR. SCOTT: The ranges you were talking of.

MR. FRENCH: It has been assumed by Swinden and others that molybdenum combines first with the ferrite. That point is in dispute. I don't know. The exact condition of molybdenum in steels has not been settled. The most comprehensive study in recent years, I believe, has been the work by Swinden. He considers that molybdenum is distributed throughout the ferrite, somewhat in the nature of a solid colloidal solution. These present tests were not conducted with the idea of determining in what state the molybdenum existed in the steel, but as explained previously, they have been examined in the light of Swinden's work, to see whether his explanations would fit in with the results

obtained and in general they seem to do so. That does not mean that Swinden's hypothesis is the correct one or that it is the final answer. Molybdenum is considered as a carbide-forming element, when present in sufficient proportion, but with low carbon and less than 1 per cent molybdenum, we don't find any evidence of special carbides under the microscope when using ordinary etching reagents and a magnification of 500 or 1000 diameters.

MR. VANNICK: My attention has been called to some chrome molybdenum steels containing about 0.5 per cent of molybdenum, in which etching was done with concentrated nitric acid, about 50 per cent nitric acid and water, in the pearlite steels. In that steel the peculiar feature was the yellow stains that appeared over the pearlitic areas, which we took to be oxide in the molybdenum. I could not say whether that came from the ferrite in the pearlite or whether it came from the carbide in the pearlite, but at any rate it appeared over the pearlitic areas and we were not particularly interested in it at the time, but if it is worth anything it probably will be interesting for some one to try that process and locate, if possible, the position of molybdenum in the structure.

HEAT TREATMENT OF LARGE FORGINGS BY OIL, GAS AND ELECTRICITY

By W. E. McGahey

THE term "large forging" is very broad and may mean any class of forging having sufficient weight to be termed a large forging. Many so-called large forgings are made for commercial purposes which require practically no actual heat treatment other than an anneal to pass the specifications under which the forging is made. As this class of work does not require a great deal of attention and accuracy in heat treatment, being gen-

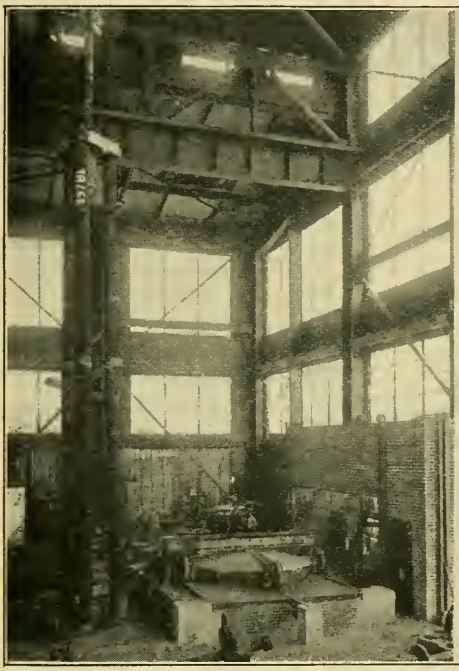

Fig. 1—Three 30-foot hollow forgings having a diminishing wall thickness which have just been drawn from the 36-foot electric furnace at the right.

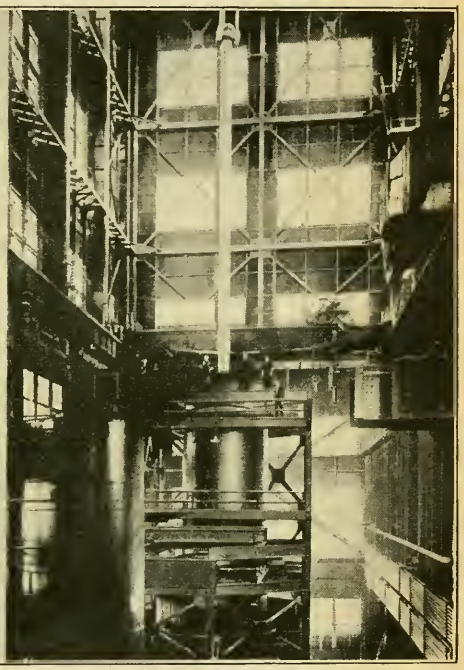

Fig. 2—Hollow ship shaft suspended over a 70-foot furnace. Courtesy Allis-Chalmers Mfg. Co., Milwaukee, Wis.

erally handled in the forged condition, either oil, gas or electricity may be used with equal satisfaction as heating mediums. Which is the most practical and economical fuel depends primarily upon the locality. Oil and gas are more generally used in preference to electricity on account of the high installation cost of the latter. The term "large forging" in this case more particularly applies to large hollow forgings of a nature that requires more extensive heat treatment to pass some high specification of physical quality.

There is really but one satisfactory way of treating a forging of this type, this being to handle it in a vertical position, which is accomplished by the use of the cylindrical pit furnace. To meet this condition the forging is rough machined, (and rough bored in cases, where the inside diameter

A paper presented before the Indianapolis Convention. The author, Wm. E. McGahey, formerly foreman, heat treating large guns, U. S. N. Ordnance plant, Charleston, W. Va.

is too small for hollow forging) before heat treating, in order to obtain mechanical uniformity in handling and uniformity of cross section for treatment. The main thing in the heat treating of large hollow forgings of this type, is to get absolute temperature control and uniformity of temperature throughout the whole charge of metal. To accomplish this is not an easy problem as the forging may be very long, small in diameter and having a comparatively thin wall. Even the wall thickness varies in some cases, being very much greater at one end than the other, making it all the more difficult to treat. Forgings having this different area of cross section are generally quenched from a constant temperature somewhere above the upper critical range and the draw temperature is split, gradually increasing from the heavy end to the lighter.

Serious defects may result from lack of uniformity in heating, such as cracks, hard spots or soft spots. Hard or soft spots are something that may never be detected while in the process of manufacture, but may cause considerable damage in service. It may be true that such cases do not very often present themselves, but it is the writer's desire to bring these points out to illustrate the importance of uniformity in heating.

Uniformity is largely dependent upon temperature control, the time element also entering. The method of control is practically the same for either oil or gas; each burner or multiple of burners in the same plane having to be individually operated, which makes temperature control entirely dependent upon the skill of the operator. As the size and depth of the furnace increases, difficulty in operating and control also increases. The baffle wall or muffle which is generally used in oil or gas fired furnaces helps the situation a great deal by breaking up the flame and distributing the heat more evenly over a large area but does not guarantee absolute evenness in heating. The electric furnace is entirely different in its method of control, being automatically operated and controlled in zones. Each zone may be made to yield the same temperature as the surrounding zones or a different temperature, thereby making it possible to graduate the temperature accurately from one end of a long forging to the other. The construction is such that the heating element in each zone is evenly distributed around the interior wall which causes the heat liberated to be the same at any point within the zone. If all the zones are operated at the same temperature then the heat liberated at any point within the furnace will be the same.

In using oil or gas, the burners must be adjusted correctly to give the proper mixture of the fuel and air for complete combustion without excess air. Excess air reduces the effective heating efficiency as a certain per cent of the heat liberated is taken to heat the excess air. Excess air also causes a great deal of scale on the surface of the forging which is not desirable. The only air to be considered when dealing with the heating efficiency of an electric furnace is the air that fills the space between the charge and the furnace wall. This is not of material effect as the furnace is tightly sealed to prevent any other air from entering. No openings are necessary other than observation vents which are kept tightly closed when not in actual use. Comparatively little heat is lost in heating the air, most of the heat produced being effective by radiation. The average effective heating efficiency of an electric furnace, of this cylindrical pit type, ranges from 70 to 80 per cent.

It might be interesting to note that the life of the electric furnace of this type is as much as twice and sometimes thrice that of either oil or gas.

By life is meant the comparative time two furnaces will last without any major repairs, when started at the same time and operated under the same conditions. In the electric furnace there is no high combustion temperature or blast of burning gases, impinging on the walls, to cause the lining or furnace wall to give away. There are numerous other minor advantages derived from the use of electricity as a heating medium in the heat treatment of large hollow forgings which it is unnecessary to discuss, such as cleanliness, lack of noise, lack of necessary storage for fuel, lack of necessity for extensive piping and blowers, etc., as these are familiar features.

Taking everything into consideration, the writer believes that you will agree with him that even though the electric furnace may be more costly to build, it has offsetting advantages in its favor, these being decreased maintenance cost of upkeep and simpler and more definite control which gives greater uniformity in heat treatment. This great uniformity is more economical in the end as a greater per cent of forgings will be accepted on a single heat treatment, thereby saving the cost of additional heat treatment.

THE EFFICACY OF ANNEALING OVERSTRAINED STEEL

By Irving H. Cowdrey

WHY is it that anchor chains, hooks, hoisting tackle and many other iron and steel parts are periodically annealed by careful contractors and engineers? To what extent is this treatment successful in producing the expected restoration of the original properties of the parts in question? These two questions must have suggested themselves many times to the intelligent man who has been brought into contact with the commercial heat treatment plant or who has been called upon to make use of the various parts commonly subjected to the treatment under consideration. Numerous answers have been tendered in the past; some of them contain a generous portion of truth, and some, in the light of modern knowledge and ideas, are quite erroneous.

In the earlier days when steel was held to be fit for cutlery and tools alone, and nothing but wrought iron would be for a moment considered as a material for structural members, it is not at all surprising to find queer ideas concerning the constitution of these different though related products. The blacksmith nicked the iron bar, broke it across the anvil's edge and noted the stringy ragged fracture like a piece of tough rickory. Hence he held that wrought iron was essentially a fibrous material. When the piece of steel rod from which he was to forge a chisel or other like implement was broken, resulting in shiny sparking surface of coarser or finer grain he said the steel was crystalline. When the chain link parted or the hook snapped, perhaps on a cold frosty morning, showing a bright sparkling, granular texture, what was more natural than to say that the iron, which he supposed to be a fibrous metal, had by some mysterious process, crystallized. We find then such terms as cold crystallization, fatigue etc., constantly appearing in the older literature on the subject. The advent of the microscope into the field of engineering made it possible to explain much, which had before been veiled in mystery, concerning the behavior of metals both under stress and heat treatment.

The first of the questions, has been answered at least by inference by several of the modern writers,* who will be freely drawn upon in the following discussion. The second question finds its answer in the results of certain tests which will be outlined and discussed later on. In order that the reader may have a clear understanding of the problem under discussion, the writer will take the liberty to survey the most modern conception of the structure of iron and steel and note the effects brought about by overstrain.

No one today questions the fact that metals are made up of microscopic granules. The size, shape and constitution of these granules depends mainly upon two factors: first, the chemical constituents of the material; second, the physical treatment which it has received. Under the heading of physical treatment the writer would include, hot working above critical range, cold working below critical range, and the heat treatment. These granules are composed of crystalline material under all circum-

*Materials of Construction, by G. B. Upton.
Materials of Construction, by A. P. Mills.
Steel and Its Heat Treatment, by D. K. Bullens .

A paper presented before the Indianapolis Convention. The author Irving H. Cowdrey is Assistant Professor Testing Materials, Massachusetts Institute of Technology, Cambridge, Mass.

stances. Their boundaries are well defined and commonly are formed by a series of planes. Between the granules, or as it is frequently expressed, at the grain boundaries and completely surrounding the grains, there exists a very thin layer of noncrystalline, or amorphous material, sometimes referred to as the amorphous cement. This amorphous material may under some circumstances be of a chemical composition identical with the grains which it embraces. Its physical properties, however, are always quite different from those inherent in the grain. It is always harder, stronger, and less ductile than the corresponding crystalline material, and tends to impart these properties to the entire mass, to a degree more or less in proportion to the magnitude of the quantity present. Under an ordinary circumstances it represents but an extremely small portion of the whole mass of metal. In this connection it should be noted that the quantity of this amorphous cement is dependent upon the superficial area of the granules and the smaller the granules the greater will be this total superficial area; hence the greater relatively the quantity of the amor-

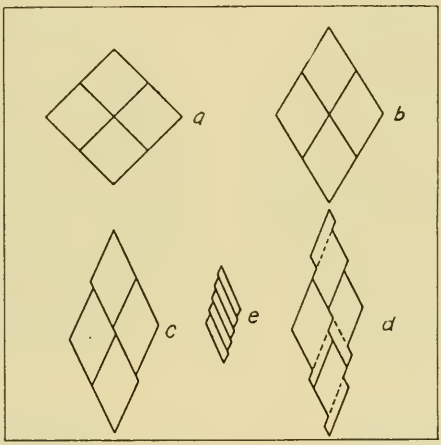

Fig. 1—Diagrammatic illustration showing the manner in which four crystals are probably distorted when subjected to various loads.

phous material. Any cause which tends to reduce the size of the granules will tend to harden and strengthen the metal and generally to render it less ductile, hence more brittle and less resistant to shock, except perhaps with some of the modern alloy steels. With this premise in mind, it will now be in order to consider the effect of severe stresses in metallic members.

Any stress, however slight, will produce distortion in the metal resisting it. This resulting disortion may be of two types; either elastic, from which recovery is complete, or plastic from which there is no recovery, or partaking in part of each type, in which case the recovery will be partial. In order to study these actions in detail let us imagine four adjacent cubical crystals shown in section in Fig. 1a. During the elastic distortion it is held that the granules are deformed but maintain their integrity and mutual positions with no displacement of one granule surface with respect to those adjacent to it, as in Fig 1 b. Upon recovery each granule returns in all senses to its original form, position and condition. Plastic distortion

is the result of either bodily displacement of the granules with actual motion of one bounding surface over the adjacent one, Fig. 1c, or shear within the granules in which one portion slides past that adjoining it. In general both types of displacement occur simultaneously as suggested in Fig. 1d. If the distortion is excessive each granule is likely to shear on a series of parallel planes as is suggested diagramatically in Fig. 1e. These parallel cleavages produce what are known as slip bands in the grains which are admirably shown in the photomicrograph Fig 2a made by Dr. R. S. Williams. Displacements of this nature are permanent and produce what is termed permanent set in the member. The effect produced in metal burnishing and glazing of bearings in service is well known. No practical man will deny the fact that the surface produced under such conditions is different from the body of the metal particularly in that it is appreciably harder. A similar change then might be expected at the surface where sliding occurs, as outlined above. Such change is due to the increase in the quantity of amorphous cement which finds its genesis in the mutual burnishing between the sliding surfaces. Moreover, if internal shear results, a portion of the metal adjacent to the planes of shear is transformed from the crystalline to the amorphous condition. From this it must be concluded that elastic distortion should produce no physical change in a metal, while plastic distortion, due to the increase in the amount of amorphous material, will tend to give greater hardness and while increasing the static tensile strength will nevertheless render the metal more brittle and less resistant to shock. Not only will the above results be produced, but successive abuse in the way of overstrain will yield a cumulative effect. Since the amorphous material is more brittle than the crystalline from which it was formed, fracture under shock will follow the planes in which it is present. The broken surface will then be made up of planes, resulting in a bright sparkling appearance generally characterized as granular. Hence the judgment of the uninformed that the metal has crystallized.

Having thus noted the evil effect of continued overstrain it is logical to attempt its removal if possible. Periodic annealing has for many years been the prescribed remedy. The question may very properly then be raised as to the efficacy of such treatment, and the extent to which metal may be overstrained and still be restored by annealing. While it has been admitted by most engineers that the effect of slight over strain may be in part, if not wholly, removed by annealing, yet there have been a certain number who have held that very excessive distortions produce results which cannot be nullified by such treatment. Moreover many have declared annealing to be completely effective only for the very lowest carbon steels. To prove or disprove this stand, a set of tests * were lately conducted at the suggestion of the writer in the testing materials laboratory of the Massachusetts Institute of Technology in accordance with the following schedule.

The material selected was a 0.20 per cent carbon steel with the normal content of silicon, manganese, sulphur and phosphorus. This was purchased as hot rolled steel 1½-inches in diameter and about 7 feet long. From this tensile test specimens were fabricated to determine its physical properties as received and also after careful annealing. The remainder of the bar was then subjected to torsion, and twisted cold until fracture was

*Mahan and Sloan. M. I. T. thesis 1920.

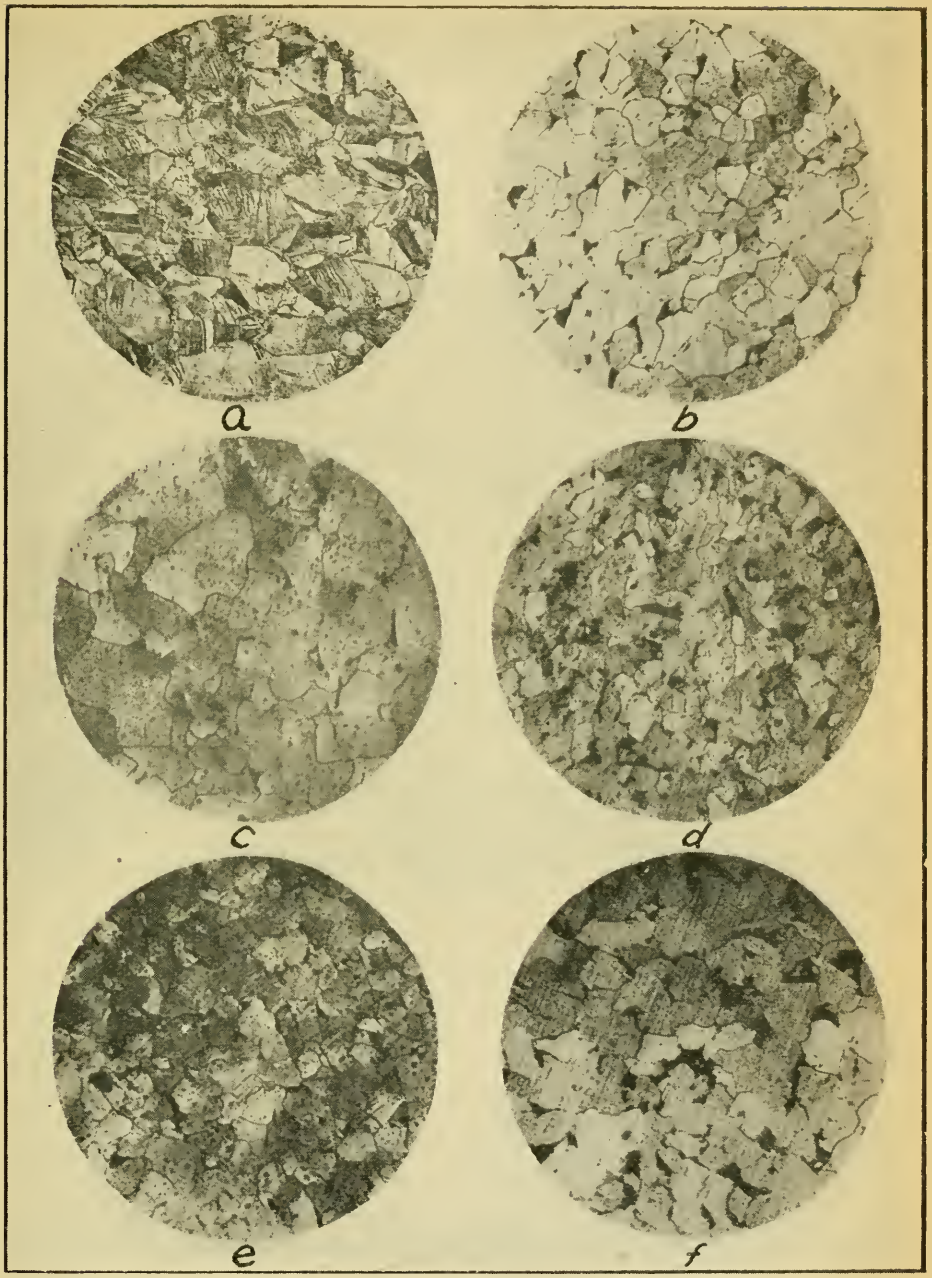

Fig. 2—Photomicrographs showing the structure of specimens subjected to various loads and heat treatments. *a*. Drawn Brass. X 75. *b*. Steel as received. X 100. *c*. Steel as Received plus Heat Treatment I. X 100. *d*. Steel after twisting. X 100. *e*. Steel Twisted plus Heat Treatment I. X 100. *f*. Steel Twisted plus Heat Treatment II. X 100.

produced. From the over strained material, tensile specimens were taken which were tested in this cold worked condition and also after having been carefully annealed. The Brinell hardness was determined under all the various conditions and photomicrographs were made to study the structure of the metal. At least two specimens were tested in each case and in every instance the values checked admirably. All tensile specimens conformed to the dimensions of the U. S. standard test bar having a 2 inch gage length and a 0.505 inch diameter with threaded ends and were tested in a universal autographic testing machine of 60,000 pounds capacity. Such a method of testing does not permit the determination of the true elastic limit. That the properties of the material were determined under tension while the over strain was produced in torsion may seem paradoxical. Such, however, is not in reality the situation since, according to Upton all permanent distortion is a result of internal shear regardless of the actual external loading. As a matter of fact it is probable that over strain by such a means is more severe than when the specimen is stressed axially, since fissures, if produced, will be inclined to the axis of the subsequent tensile specimen. While of no special significance, it may however be of interest to note that the bar as received, twisted through nearly 16¾ complete turns in a length of 4 1/2 feet or nearly 3¾ turns per foot of length.

The annealing was done in accordance with one of the two following methods which will be designated as Treatment I, and Treatment II respectively.

I. Specimen wrapped in carbon and asbestos, heated for one hour at 1760 degrees Fahr. and air cooled.

II. Specimens packed with cast iron chips in a loosely closed tube, heated at 1760 degrees Fahr. for 1 1/2 hours and air cooled. The first method gave considerable surface oxidation, while the specimens treated by the second method showed no discoloration whatever. The results of the above tests appear in the following tabulation. The values in each instance are the averages of at least duplicate tests.

Table I

Results of Tensile Tests

	Yield Stress pounds per sq. inch	Ultimate Stress pounds per sq. inch	Elong. per cent	Red. Area per cent	Brinell No.
Bar as received	46000	67850	35.7	64.4	131
As received plus Heat Treatment I	40000	68250	33.7	62.5	130
Twisted Bar	86500	95633	15.8	54.3	180
Twisted Bar plus Heat Treatment I	42200	67200	36.5	62.5	128
Twisted Bar plus Heat Treatment II	43150	69450	37.0	62.0	127

The photomicrographs representing the structure of the metal for the various conditions are shown by Fig. 2b, 2c, 2d, 2e, 2f. In the original investigation four photomicrographs were made for each condition of the metal, two on each of two planes, respectively parallel with and perpendicular to the axis of the twisted bar. Each set of two comprised one near the center and one near the edge. As was to be expected, little

change of structure was observed in the center of the bar, since the distortion was almost negligible at that point. The greatest and most significant changes of structure were observed in the longitudinal section near the surface, and it is these photographs only which have been included in this discussion.

The various data will now be analyzed and discussed. Throughout the discussion it should be kept clearly in mind that it is in general impossible to obtain perfect checks in the testing of any material whatever. With very homogeneous steels variations of several percent must be expected even when tests are conducted on adjacent specimens. Hence variations of two or three thousand pounds per square inch in yield stress and ultimate stress and one or two percent in elongation and reduction of area are entirely negligible, within the above limits, then, there

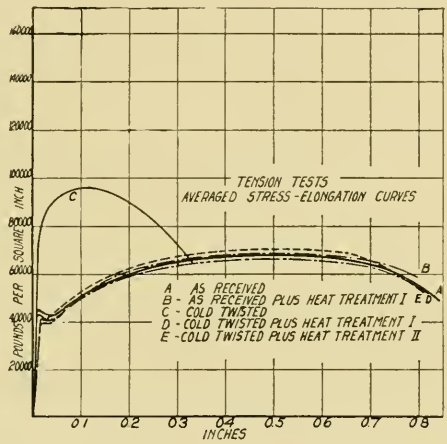

Fig. 3—Autographic Load-Elongation Curves. These curves are reproduced from the charts taken from the testing machine. Curves show the average result for each set of tests.

is perfect agreement between the figures in the first two and last two rows. Among other things this would indicate that the material was very well annealed when purchased. The results recorded in the center row showing properties after cold twisting are of an entirely different order. The yield stress has been doubled (see discussion of the graphs), while the tensile stress and hardness have been increased about one half. On the other hand, the ductility is less than half that evidenced by the normal metal. This difference is entirely in accord with results obtained from tests on cold worked material in general, such as cold rolled steel, extruded metal and wire provided the material is of such dimensions and so fabricated that the effect of cold working has pentrated well into the interior. With the increased hardness and decreased ductility is would seem obvious that the metal is in a state quite unsatisfactory for resistance to shock even though its static strength has been increased. Overstrained hooks, chains and-so-forth, have suffered alteration in their physical properties along just such lines as this, the difference being solely one of degree. As before intimated, the last two rows show that the

original properties have been completely restored by the heat-treatment to which the steel was subjected.

The autographic load-elongation diagrams are reproduced in Fig. 3. In redrawing these diagrams the data for each set have been averaged and are indicated by a single line, to simplify the comparison of the results. In addition, the usual obscuration of the yield point by overstraining is well marked. The sharp jogs, with decrease of resistance on the part of the specimen noted in the original and anealed specimens, corresponds to the sharp and decided drop of the beam usually sought after by the engineer. No such phenomenon marks the yield to the over-strained material necessitating a somewhat arbitrary determination of that value which commonly taken at 1 per cent elongation.

The explanation of these agreements and variations is to be found in the photomicrographs. Fig. 2d and 2c shows a normal granule arrangement of reasonable size without evidence of grain distortion. Here might be expected the usual quantity of amorphous cement hence the normal properties of low carbon steel. In Fig. 2d, marked distortion of the granules appears, indicating both motion on adjacent boundary planes, and the formation of myriads of internal clearage planes with the consequent increase in the amorphous material. This great increase in the cement produces the change in the physical properties noted previously. Fig. 2e and 2f show clearly the readjustment of the granules which has been accompanied by the return of the excess of amorphous cement to its normal crystalline form, resulting in the complete restoration of the original properties.

As a result of the foregoing theory, description and analysis the following conclusions are in order.

1. Overstrain of metal when its temperature is below the transformation range, results in the production of undesirable properties tending to render the metal unfitted to withstand sudden and shock loads.

2. If possible such effects should be eliminated for the safety of those using devices which have been so abused.

3. Proper annealing suffices to completely restore the normal properties of low carbon steel even after the most severe over strain.

ORGANIZING RESEARCH TO MAKE IT PAY DIVIDENDS

By W. P. Woodside

THE foregoing subject upon which it was suggested that I speak demands at the outset a little analysis and definition. There can be no question but that there are hundreds of ways in any business of so carrying out its necessary and peculiar research that the ultimate financial return to the institution is enhanced. The greater or less degree of these increased returns measures only the effectiveness of the methods used. We may, I believe, safely accept the view that research can pay dividends without discussion or further elaboration of the subject. There is no general accord on the relative place a research department shall hold in an organization—no uniformity of opinion as to the proportional amount of funds which should be devoted to its use, and no agreement on the amount and quality of equipment and personnel which should be allotted to it. In some industries, both of a large and small nature, research occupies a relatively important and responsible part —in others, its role is but the smallest if not indeed noticeable by its entire absence. There should be no doubt in view of the present day traditions of business that work of the sort we are discussing has a real, definite and valuable place. It seems incomprehensible that some modern businesses give it no room, no encouragement and no thought.

It is probable that the popular adoption of research methods has failed, due in part, to a psychological barrier built up around the word "research." Research, the word, possesses a certain strong dignity—it has been used to denote principally a high type of technical endeavor. Its popular use has surrounded it with an altogether faulty meaning whereby the impression has become but too firmly established that none but the highest types of technically trained experts can suitably carry on the work of research. We have come to understand that this lofty and remote type of activity was something for us to marvel at and consult deferentially, but we have perforce regarded it cooly as a brother, or fellow worker. Research means none of these super qualities. it only means "to look into again"—"to re-search." It is nothing if not based on simplicity—on the simple act of witnessing again and again the familiar and known things until knowledge of them becomes so full that a new and better step or method suggests itself. Progress in growth and research is but the intelligent directing of this growth in any or all of the influences which contribute to this natural process.

For our purposes here, then, let us discard the purely technical meaning of research and define it to mean all those activities of investigation into any and all phases of plant or manufacturing operations. We emphasize the word "all" for our meaning fundamentally includes the movements in every branch of the entire process. As a general proposition we do not think the statement will be disputed for an instant that any single production operation can in some way be bettered or made to yield more effective results. The old saying which relates that nothing is so good but that it may be improved, applies with equal truth to life in general and production operation No. 11 on part No. 13783 which calls for the drilling of a single one-quarter inch hole. The fact that even this minor step can be improved holds at once the incentive which makes effort possible and as well the hope

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A paper presented before the Indianopolis Convention. The author, W. P. Woodside, manager methods and standardization departments, Studebaker Corporation, Detroit and South Bend, Indiana.

of advancement and progress. Were we compelled to admit that even in the most elementary operations no farther betterment could be hoped, we must admit the eventual stoppage and stagnation of all progress even to that of civilization itself which only measures its growth through the ever better and better utensils with which it maintains and carries on life. The research agency of which we speak is composed of many members. In a way each worker individually is a member of it. At any event it is a large group of workers or better still a vast potential force lying close to the heart of all operating activities and which has in its care and for its responsibility all of that businesses' hope of growth, advancement and success. It is no light load of responsibility that we are placing on research, in fact, it is pretty nearly the whole burden of future achievements which we are demanding and I believe we are not alone in thinking that no business can eventually prosper or even hold its own whose members, large and small, from the highest executive down to the humblest workman are not individually research workers in the sense we have endeavored to define the term. Particularly in this day of renewed competitive strife do we need men at the desk and at the drill press who will hold up their own work to the searching and researching of their own eyes, intent upon recognizing the little opportunities offered to each one to institute the new steps which mark progress in any line. Were it possible for us to stop at this point and get an expression from you as listeners as to your opinion of what has gone before I imagine we would hear somewhat such expressions as these:

"Surely, we agree, but how are we going to get such workers?"

"You've said nothing new—you're as regular as a party candidate."

"Utopian dreams are all right but—business is business, etc."

The development of individual constructive activity regardless of the individual's high or low position in producing operations is not novel. The theory which supports belief in personal initiative in even the most restricted of jobs is not new. The underlying and crying need of teaching and inculcating this principle, plant-wide, as it were, is a truth at once so vital and so elementary as to be apt to escape the sort of recognition which results in accomplishment. We are dealing with a principle, not a mere routine activity, when we concern ourselves with research in its total plant aspects. You cannot always apply a principle and make it bear immediate fruit in terms of measureable increments of achievement, but you can always teach a principle to those about you, be they friends, associates or fellow workmen. And if your teaching is persistent enough and intelligently enough directed, you can in time begin to realize results from its greater or less acceptance by your listeners. This is the fundamental fact of research endeavor—that it can be taught; that it can be inculcated as a mental principle and nourished into a positive healthy growth. Its method of attack is that of quiet, persistent infiltration, and with entire absence of violent gas activity. You can teach a man perhaps to protect his own safety by Safety-First campaigns, vivid posters and safety directions, stencilled thrice dimensionally on ceiling, walls and floor, but you can't make a man a good upright man by telling him to be so in print wherever his weary eye seeking rest and relaxation chances to pause. Neither can you form and cultivate that incomparable research faculty dormant, but still present in average individuals, by the blatant instrumentality of pictorial or printed appeal. As

the moral virtues in man are implanted far better by example than by precept so is that virtue of personal initiative best nurtured by similar means.

And this brings us down to the practical means by which we must realize the goal of widespread research effort throughout the plant. I have said enough I am sure, relative to the subject of teaching research as a principle to the whole plant to presuppose the existence of a teacher. Your research department as a department needs but one man, but he must be a teacher in every sense of the word. It is not by any means sufficient that he is able to talk or expound or orate—that would be to miss the point altogether. He must above all be endowed with that subtle faculty of educating which makes use of men's ambitions, which avoids awakening their reasonless resentments and gets across its message of real knowledge from the angle of common sense rather than of technicality. Such men are rare but they do exist and they are fundamental to our scheme. A man of this stamp needs helpers but he finds these helpers scattered here and there throughout the plant wherever personalities react favorably and right here is built up the main staff of research workers. And from this nucleus fingers sooner or later reach out farther and farther into all operations. Bear in mind if you will that we are now talking the practical ways and means. It is eminently practical and possible to find and select such a man as we have described And if it is practical and fundamental to find a high type of man to head any business enterprise it is equally practical and fundamental to seek a high type of man to organize research development.

It goes without saying that our research director must possess exact technical knowledge and that he must have at his disposal ample scientific equipment to carry out whatever technical work is required. He should have at his command the facilities of a laboratory equipped to do the kind of work which the particular business in which he is engaged, requires. There seem to be two ideals of laboratory work. Some laboratories seem to function wholly from within; that is, the laboratory staff recognizes a problem in the plant, retires to its sacred precincts, solves the problem, passes the solution on to the shop and is finished. In the meanwhile, countless other equally important problems suffer from lack of attention for the efficiency of this scheme depends entirely on the efficiency of the vision of the laboratory in recognizing a problem when it sees it—and laboratory eyes are always directed from without and not from within the job. To our mind the plant laboratory should be entirely and completely a checking institution. It should be a place of consultation; it should be the place to which problems are brought by those who personally are experiencing them and it should be the place where the theories and deductions of the plant are proved or disproved. In other words, the laboratory should be the servant, not the master. It should become the melting pot of the research staff—that and nothing more. It is only by this conception that we can hope to break down the barrier which most certainly exists today between workman and scientist, between job and technicality. And the putting of technicality into job and job into technicality can only mean, in the measure to which we succeed, the attainment of growth and progress from the basis of continual searching and researching.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A DISCUSSION OF PROF. H. F. MOORE'S PAPER ENTITLED, "THE FATIGUE OF METALS UNDER REPEATED STRESS"

By J. M. Lessells

THE remarks of Professor Moore to the effect that most of our design formulae can be likened to cartoons, would seem at first glance somewhat revolutionary, but the truth is apparent and engineers can profit by them. To state that the "endurance limit" seems to be more closely related to the ultimate stress rather than to the elastic limit may create wrong impressions in the minds of some and these statements should be approached with caution. Referring to Fig. 1, which shows the relative values of elastic limit and ultimate stress for a 3 per cent nickel steel, one in the annealed and the other in a heat-treated condition, it will be noted that the ratio of elastic limit, to ultimate stress for these steels is 0.3 and 0.75. Therefore if the working stress is based on the ultimate stress and is fixed at ½ of the ultimate stress, then the elastic limit in the annealed state would be exceeded, and permanent set would occur. It therefore seems misleading to base the endurance limit on the ultimate stress since working stresses cannot be so fixed.

With reference to the use of design formulae, Professor Moore has very

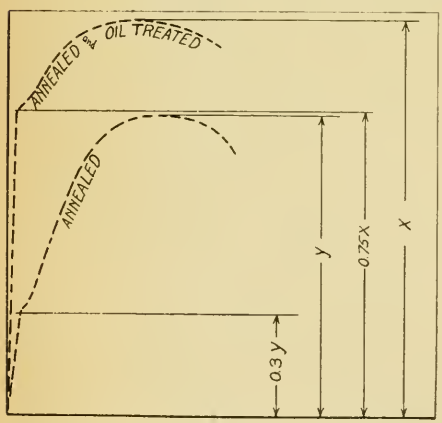


Fig. 1—Diagram of Apparent Elastic Limit and Ultimate Stress

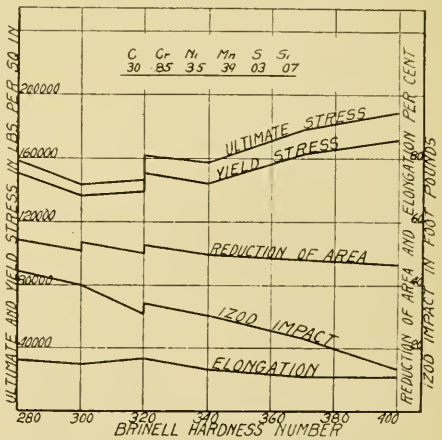


Fig. 2—Characteristics of Nickel Chrome Steel

aptly said that these should be applied with caution, but when an attempt is made to draw a comparison between Brinell number and endurance limit

A written discussion of Prof. Moore's paper presented before the Pittsburgh Chapter, and published in TRANSACTIONS of January 1922. The author, J. M. Lessells, is connected with the Westinghouse Electric and Mfg. Co., Pittsburgh.

the cartoon is becoming distorted, because the Brinell test was never intended for such a service. One of the reasons advanced for such apparent agreement between first, endurance limit and ultimate stress and second, between endurance limit and Brinell number is that too many steels have been compared on a common base, and after all, alloy steels have very little in common, with carbon steels. A suggestion put forward for future work is to compare all the varying characteristics of any one steel such as is shown in Fig. 2, which represents the characteristics of a nickel chrome steel, rather than endeavoring to correlate different steels. In this way the problem of comparing different steels will be simplified, but will always be more or less complex. Attention is drawn in Figure 2 to the similar manner in which reduction of area and Izod values respond to heat treatment variation. Both of these relate to crystal formation.

In Table I is shown the physical properties of three different steels each having the same Brinell hardness. If what has been suggested by Professor Moore, is true then steel *A* with 20 per cent reduction of area is as good in resisting fatigue as steel *C* with 50 per cent reduction of area, and all the past test data gathered around such tests may be relegated to the waste basket. This, in a word, with our present knowledge, is unthinkable, so let us move slowly. The idea advanced by Mr. W. J. Merten that the

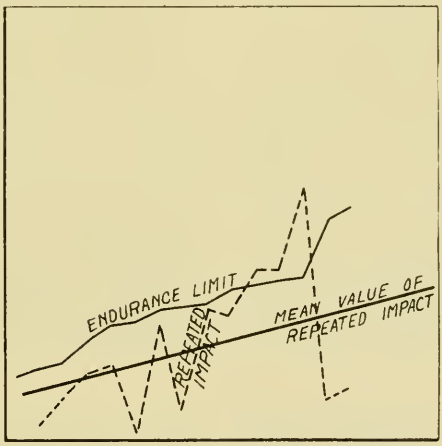


Fig. 3 Relation of True Elastic or Endurance Limit to Repeated Impact

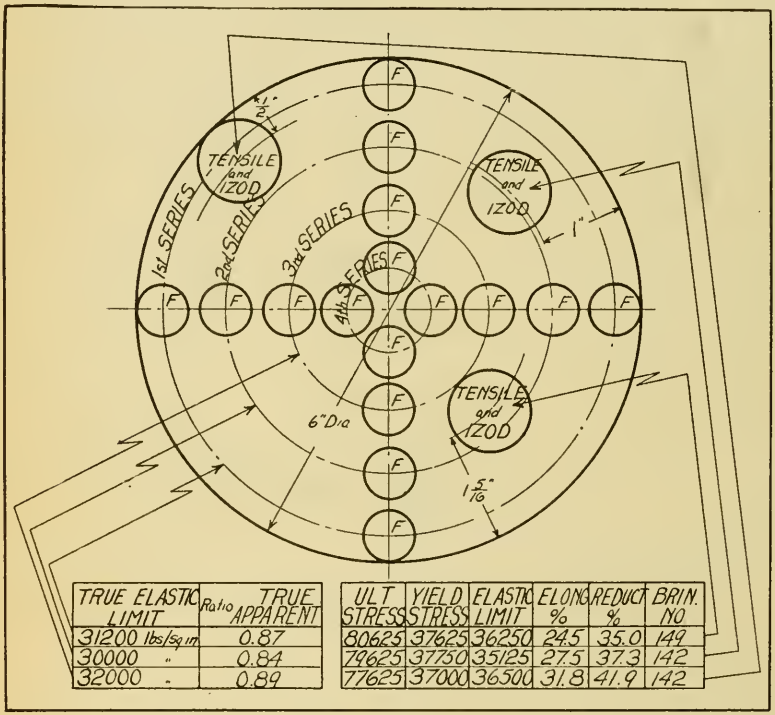
common meeting ground should be on a basis of a common structure, that is pearlitic, martensitic, or troostitic, after each steel has been explored, is a good one and worthy of further consideration.

As stated by Professor Moore, there seems to be no reason why impact tests should be related to endurance limit since each represent different conditions. The impact test is more or less localized by the notch while the endurance test is not so localized. This does not hold to the same extent with a repeated impact and there are reasons for believing that this test is some measure of fatigue. In Fig. 3 is shown plotted the values given by Professor Moore for endurance limit and repeated impact. It will be noted that a mean line has been drawn through these points apparently showing this relation, if allowance for possible notch error is considered. This is a very interesting phase of the subject. Our laboratory is proceeding

along such lines, because this is a very simple test to make, and it has been suggested recently that in the Stanton test, the number of blows required to fracture the test specimen is a measure of its resilience or the work required to cause the fracture. Summarizing these various points we have;

1. The results of Professor Moore indicate that endurance limit may possibly be related to ultimate stress. Since a comparison is made however, on many steels of entirely different characteristics this relation should be accepted with caution because there are evidently other factors involved.

2. The results further show that Brinell number is related to endurance limit but by "reductio ad adsurdum" this scarcely seems possible because the Izod test is related to reduction of area and the value of the Izod test results having been established, it seems wrong to discard these, a thing which must be done if Brinell number is to be a criterion of endurance.



TRUE ELASTIC LIMIT	Ratio	TRUE APPARENT
31200 lbs/sq in		0.87
30000 "		0.84
32000 "		0.89

ULT STRESS	YIELD STRESS	ELASTIC LIMIT	ELONG %	REDUCT %	BRIN. NO
80625	37625	36250	24.5	35.0	149
79625	37750	35125	27.5	37.3	142
77625	37000	36500	31.8	41.9	142

Fig. 4—Shows location of test specimens and results obtained in the test of a 6-inch bar.

In Fig. 4 is shown the location of test specimens and part of the results obtained in the investigations which are being carried out in our laboratory on comparatively large sized material. The results shown were obtained in testing an annealed 0.44 per cent carbon steel. On the right hand side are shown the tensile properties taken from the region indicated, while on the left are shown the values of the endurance limit or true elastic limit as determined by tests similar to those described by Professor Moore. In this case each series of four fatigue test pieces gave the stress curve for determination of the endurance limit. This particular material was held at 850 degrees Cent. for 3 hours and cooled slowly in the furnace. The ratio of

true elastic limit or endurance limit to the apparent elastic limit is shown also. For properly annealed material there seems to be no difference between the outer and inner layers as far as fatigue endurance is concerned. We are

Table I

Characteristics of Three Different Steels

Material	Brinell No.	Ultimate Stress pounds per sq. inch	Elastic Limit pounds per sq. inch	Elong. per cent	Reduction Area per cent
A	414	190,000	104,000	8.6	20.2
		192,000	107,000	7.9	19.2
B	414	202,000	130,000	6.1	19.9
		198,000	127,000	6.3	22.4
C	414	191,400	168,000	14.2	53.3
		202,000	171,000	13.1	50.4

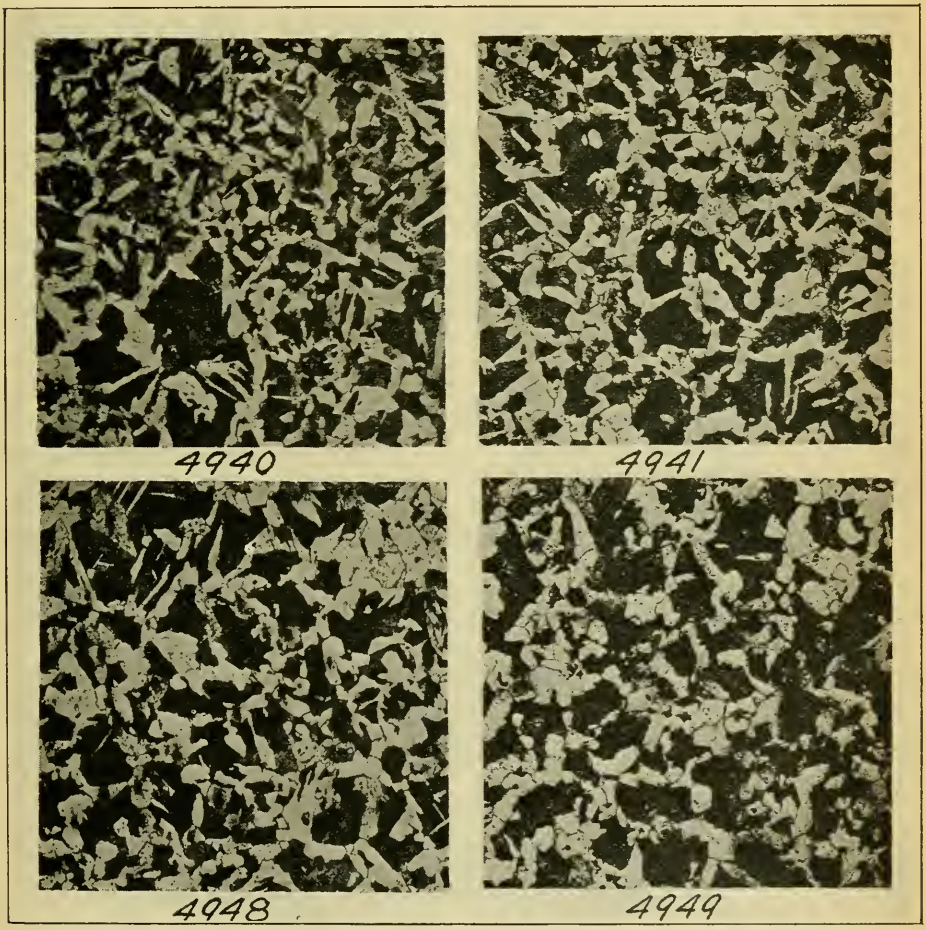


Fig. 5—Shows photomicrographs of four specimens tested.

still proceeding with these tests in our laboratory and it is still too early to draw any conclusions.

In Fig. 5 are shown a few photomicropraghs of this material indicating the characteristic pearlite structure of such steels. In Table II, is given the location of each, together with the stress conditions.

Micro photographs 4940 and 4948 were taken from the end of the test piece in the region of zero stress while the others were taken at the center in the region of maximum stress. No. 4941 is the structure obtained from the test which did not fail under 31,000 pounds per square inch stress in over

Table II

Stress Conditions and Locations of Photomicrographs Shown in Fig. 5

Photomicrograph No.	Series	Stress pounds per square inch	Number of Repetitions	Remarks
4940	1	zero	.....	.....
4941	1	31,000	8,671,000	Not broken
4948	3	zero	.....	.....
4949	3	33,000	1,772,000	Broken

eight and one-half million repetitions, while No. 4949 shows the structure upon which a stress of 33,000 pounds per square inch caused failure at slightly over a million and a quarter repetitions.

The writer wishes to express his thanks to the society in general and to Professor Moore in particular for making such a valuable contribution to this study of fatigue, and also for the liberty in being allowed to contribute this discussion in which the Westinghouse Electric & Mfg. Co. has allowed him to publish some of the results obtained in their laboratory.

AUTHOR'S CLOSURE

I have read with much interest the discussion by Mr. J. M. Lessells on the subject of fatigue of metals. With Mr. Lessells' feeling that tentative conclusions reached should be carefully examined, and used with caution by engineers I am in hearty agreement. I would like, however, to point out one or two points in his discussion with which I find it impossible to be in full agreement.

In the first paragraph of Mr. Lessells' discussion he speaks of fixing the working stress at one half the ultimate stress of the steel under test. I am sure nothing either in the written or the oral presentation of my paper would justify fixing the working stress at such a value. At Pittsburgh I did say orally that the endurance limit under reversed stress in flexure usually was about one-half the tensile strength, but I am very sure I never advocated using a working stress as high as the endurance limit, of course, any working stress should be far below the endurance limit if the material is subject to repeated stress. Moreover, it must be borne in mind that the determination of an endurance limit for reversed stress in no way releases the designer from considering the possibilities of static failure of machine parts, nor from considering working stresses in relation to the elastic limit or the yield point of the material. He must consider both static strength and fatigue strength. For some machine parts, for example, most "dead"

axles the elastic limit or yield point of the material is of prime importance, for others, for example, many "live" axles the endurance limit is of prime importance. For nearly all machine parts ductility is of importance as a safeguard against sudden shattering failure under the occasional heavy shocks of service. Later in his discussion Mr. Lessells speaks of discarding Izod test results and ductility tests if the endurance limit is accepted. Of course, nothing of the sort should be done. The fact that fatigue failure may occur does not in any way lessen the necessity of having material which has a high enough yield point so that it will not be permanently deformed in service, nor the necessity of having tough, ductile material which under occasional overload can withstand slight distortion without shattering failure. The user

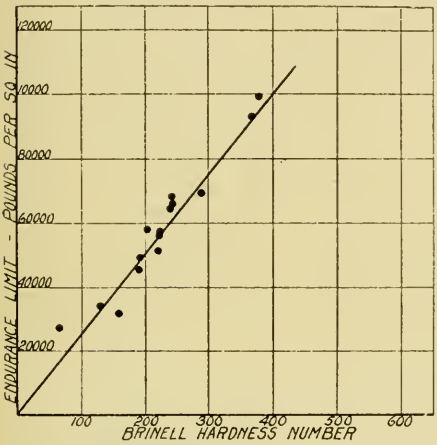


Fig. 1—Relation of Brinell Number to Endurance Limit

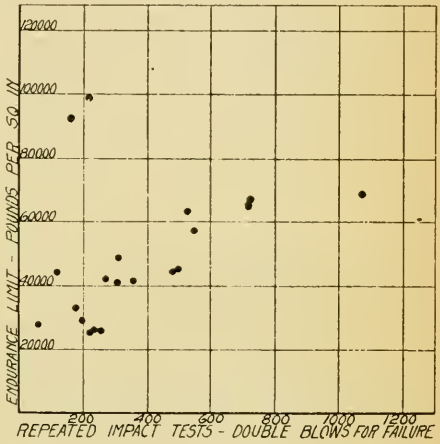


Fig. 2—Relation of Repeated Impact to Endurance Limit

of metal must never confine himself to one viewpoint, nor to one test for acceptibility of metal.

With reference to correlation between Brinell hardness and endurance limit under reversed stress the obvious answer to Mr. Lessells' "reductio ad absurdum" is to restate the fact that such correlation was found experimentally, as is shown by Fig. 1. Since the publication of the results of the investigation of the fatigue of metals at the University of Illinois, additional confirmation of this general correlation between Brinell hardness and fatigue resistance has been given first by Dr. McAdam of the U. S. Naval Engineering Experiment Station, second, in a letter from Mr. Gough of the British National Physical Laboratory, and third, in conversation by Dr. Gillett who is conducting fatigue tests at Cornell University. The results of the last-named tests indicate that this correlation becomes rather poor for Brinell hardness numbers above 400.

Moreover, it is not at all evident that such correlation is absurd. For some time it has been an observed fact that there was a fair degree of correlation between Brinell hardness and ultimate tensile strength. Microscopic examination of the process of fatigue failure shows it to be not a plastic deformation, but a progressive tearing a part or shearing apart of small particles of metal. It hardly seems unreasonable that such a progressive tearing or

shearing should be related to the tensile or the shearing strength of the metal, and to the related property of Brinell hardness.

In answer to Mr. Lessells' criticism of the attempt to find correlating physical properties for all grades of steel, and his proposal that such correlation should be sought only within narrow limits of variety of steel, the obvious answer is that with tests covering a fairly wide range of kinds of steel, including both carbon steel and alloy steel such correlation was actually found. This general conclusion has been checked by the results of Dr. McAdam's extensive tests, although he has interpreted endurance limit somewhat differently from the interpretation given at the University of Illinois.

Mr. Lessells' statement that "alloy steels have very little in common with carbon steels" seems altogether too sweeping, and it is difficult to see anything more than a bare assumption behind Mr. Lessells' suggestion that in the future testing engineers should refrain from trying to correlate test results for different steels. How shall we decide which kind of steel to use for a machine part if we cannot correlate test results between different kinds?

In Mr. Lessells' Fig. 3 he has plotted a "mean line." He has not shown the scales used in that figure, and a reference to the original figure (Fig. 38, Bull. 124, Eng. Exp. Sta. Univ. of Ill.) shows that there is no scale for abscissas, but that the diagram merely shows values for steels placed one after another in order of the magnitude of endurance limit developed. In such a diagram, without scale values for abscissas any "mean line" has no significance whatever, and the "mean line" in Mr. Lessells' Fig. 3 should be discarded. In the accompanying Fig. 2, the lack of correlation between repeated impact tests and endurance limit is clearly shown, the results being from the test data given in Bulletin 124. This lack of correlation does not mean that we must "throw into the waste basket" the results of repeated impact tests, merely because such results do not seem to be a measure of fatigue strength under oft repeated working stresses. Such lack of correlation in no way lessens the force of the practical findings by a prominent British automobile firm, that the repeated impact test picks out good material to resist the occasional heavy shocks of automobile service.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

ANSWER. By R. H. Southworth, Betz-Pierce Company, Cleveland, Ohio. Needle bar stock is a bessemer screw stock having a very bright smooth surface due to cold drawing. It is drawn to exceedingly close accuracy as to size. It machines freely in automatic screw machines and is particularly adapted for application to various automatic devices and appliances. A high surface finish lends itself well to nickel plating where parts are to be so treated. A few important applications of this material are: Its use in adding machines, addressing machines, billing machines, computing machines, moving picture machines, phonographs, sewing machines, typewriters, vacuum cleaners, etc.

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

ANSWER. By T. G. Selleck, of Chicago, Illinois. Many tests have been made to determine the variations of temperature between the interior of carbonizing boxes and that of the furnace chamber and the results have been carefully charted.

While a large majority of these tests prove that the box temperature, on an average, is much below that of the furnace, the two charts shown here indicate that it is not impossible to have a reversal of those conditions. In making these particular tests, boxes were especially fitted with protecting tubes for the thermocouples reaching to the inside center of the box while another thermocouple was suspended directly over the box in the heating chamber of the furnace and within ½-inch of the cover of the box, the distance between the hot junctions of these couples being about four inches.

In the charts shown the solid line indicates the temperature of the furnace and the dotted or broken line that of the interior of the box. One of the most pronounced cases of excess temperature inside the box is shown in Fig. 1. In this test it is shown that the temperature within the box may at times be very much higher than the furnace temperature. The operator may be wholly unaware of this condition, and with no way of knowing anything about it until the operation is completed and the ruined work tells the story. In this instance it will be observed that the temperature of the interior of the box exceeded the furnace temperature over 200 degrees Fahr. 3½ hours after charging. After the fire had been turned off and the furnace temperature reduced, the interior temperature continued to rise while the furnace temperature fell very rapidly. The two temperatures could not be brought into equilibrium, as the chart in Fig. 1 shows.

Oftentimes operators find conditions in their carbonized work, such as excessive brittleness, peeling or spalling of the case, for which they appar-

ently can find no cause. Such physical conditions in the treated pieces arise sometimes, in fact more often than not, from operating conditions such as are represented in this chart, and of which the operator has no knowledge whatever unless he makes a very close examination of the carbonizing equipment. In looking for the cause of these conditions in the test, it was discovered that the box was defective. There was a small hole in the box, and the hole was not observable when the box casting was new because of scale that covered it. Finally this hole developed into a very convenient entrance for oxygen, which combined with the carbonizer and produced a lively combustion within the box. Without the presence of the pyrometer thermocouple in this box, the operator would have no means of knowing why his results did not conform with previous records. Without the thermocouple there would not have been a reduction of the furnace temperature,

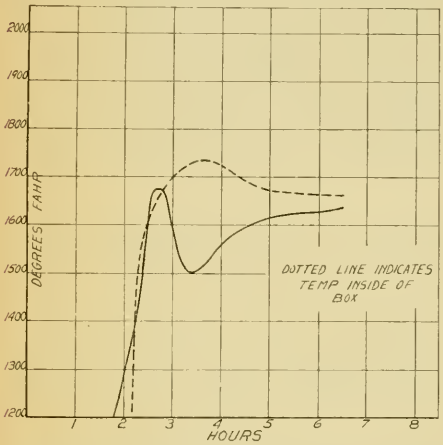


Fig. 1—A pronounced case of excessive temperature inside of carbonizing box.

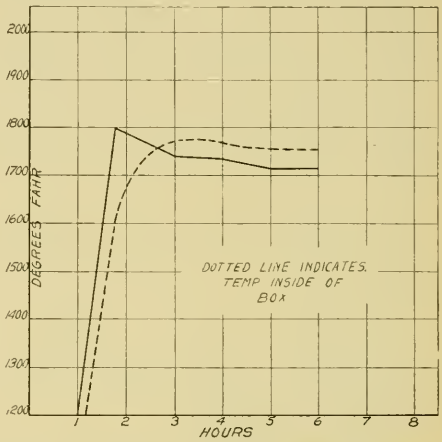


Fig. 2—Excessive temperature within carbonizing box due to an imperfect carburizer.

and there is no telling to what temperature the interior of the box would have gone, but it is certain that it would have been so high that over-carbonization would have resulted.

Fig. 2 is the record of another test in which the box temperature was above the furnace temperature for several hours. In this instance, however, we find a different cause, the use of an imperfect carbonizer. By imperfect is meant a carbonizer that upon its first use is so fully of highly combustible matter, that it almost flares up when subjected to a temperature above the ignition point of a heavy oil. Under such conditions the internal combustion is started at the very beginning of the operation and increases as the temperature of the furnace rises. In this instance the pyrometer told the story and the operator was able to save the material.

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION No. 9 In carbonizing does not the carbon increase slightly even in the core section?

ANSWER. By T. G. Selleck of Chicago, Illinois. The writer went into this question very thoroughly some years ago and after careful investi-

gation satisfied himself that if the carbon content of the core of carbonized steel shows an increase, it was due to one of two things. First, faulty heat treatment after carbonization, or second, an excessive temperature during the carbonizing period. If a test bar of known carbon content is carbonized and is allowed to cool down in the carbonizer, and is afterward fractured before any heat treatment is applied to it, the fracture will show the exact physical condition of the metal during the carbonizing period. The structure is very open and irregular and there is no well defined line between the case and the core. If the center of the core is analyzed at this time, it will probably show a slight increase in carbon content. If the bar is then quenched at the critical temperature of the original metal and again analyzed, the core should show its original carbon content. This is true only where the carbonizing temperature is not more than 200 degrees Fahr. above the critical temperature of the steel. If an excessive temperature is used there will be a permanent increase of the carbon content. The fracture of the untreated carbonized bar shows how very easy it is for gases to permeate the highly expanded metal, and in the slow cooling, some of the carbon may become deposited far beyond the mass of the element introduced.

In the quenching at the proper temperature, the carbon is segregated at the surface of the metal and the vagrant atoms of that element lying deeper down seem to fly out to join the mass. Many tests have shown that even on very thin sections there will be no increase of carbon content in the core if proper heat treatment is applied, but the single quench method will undoubtedly leave the excess carbon wherever it may locate itself, because the single quench temperature is usually too low to correct the core. If careful double heat treatment is given carbonized parts, the core should maintain its original carbon analysis.

QUESTION NO. 10. *What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?*

QUESTION NO. 11. *Has high speed steel ever been carbonized and if so what were the results?*

ANSWER. By S. C. Spalding, Metallurgist, Halcomb Steel Co., Syracuse, N. Y. The carburizing of high speed steel in the same sense that machinery or low carbon case hardening grades of steel are carburized; that is, the production of a hard case or shell on a soft core, has never, so far as I can learn, been attempted commercially. Carburizing action on high speed steel is resorted to at times in cases where improper heating has caused the burning out or removal of some or all of the carbon in the portions of the steel at or near the surface. When the steel in this condition is quenched from the hardening heat the portions where the carbon has been lowered or removed will not harden and if the tool is such that this soft surface cannot be removed by grinding, the tool will be useless. In cases where the making up of a new tool would be very costly, it will usually be worth while to try and salvage the decarburized tool by a carburizing process. Sometimes this is done by packing the tool in compound or charcoal and heating it to a hardening heat of 2200 to 2300 degrees Fahr., holding it for a short time at heat, then quenching from the pot. This method while sometimes successful, is very risky as it is impossible to see what is going on in the pot and very often due to the high temperature attained and the absorption

of too much carbon the cutting edges will be melted away and the tool hopelessly spoiled.

A longer but much safer method of treatment is to pack the tool in a mixture of old and new compound and heat it to 1650 degrees Fahr., hold for two to three hours, depending on the depth of decarburized zone, then let the tool cool off in the pot, which has been removed from the furnace. When cold, remove the tool clean it off thoroughly, then harden it in the regular way, keeping the temperature 2250 to 2300 degrees Fahr., and watching very carefully for signs of blisters. If the hardener doing this work is experienced enough to judge the proper mixture of compound and time to run it at carburizing heat, an otherwise spoiled tool can be redeemed. The great danger lies in getting the concentration of carbon on the outside too high, which lowers the melting point and causes any fine edges on the tool to blister and melt at the hardening heat, or even if not melted, to be brittle and tend to crumble in use.

Summing up, we might say that by a carburizing process an otherwise spoiled tool can be redeemed and made to do some work, but that the job is a risky one, requiring considerable care and experience and we might almost add, good luck.

QUESTION NO. 12. How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

QUESTION NO. 13. A swaging die for tubing receives 3600 blows per minute. It has been found that a scleroscope hardness of about 95 is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?

QUESTION NO. 14. What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?

QUESTION NO. 24. Do steels of similar composition respond similarly to case hardening operations, and providing these are properly conducted, will satisfactory results always be obtained?

QUESTION NO. 25. What is the difference between magnification and enlargement in taking photomicrographs?

QUESTION NO. 26. Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 28. What is the role of manganese in steel?

QUESTION NO. 29. Does the macrostructure of a piece of steel ever reveal imperfections which cannot be observed under the microscope or through chemical analysis?

QUESTION No. 30. How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION No. 31. What is the effect of oxidizing gases at low pressure on heated iron?

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

MORE ABOUT CHEMICAL ENERGIZERS. By H. B. Knowlton. *Forging and Heat Treating,* Vol. 8, Page 141.

Exception is taken by Knowlton to statements made in an article by C. E. Carpenter entitled "Specifications Which Don't Specify." Experiments were conducted to show (a) that energizers do have an influence on charcoal which they are not actually in contact with, (b) that the energizer in impregnated pellets will be practically as efficient as those on coated pellets and (c) that good energizers are not necessarily insoluble in water. The need of uniformity in commercial carbonizing compounds is pointed out.

FERROUS AND NONFERROUS MATERIALS

IRON AND STEEL CLASSIFIED FOR DESIGNERS. By W. J. Merten. *Blast Furnace and Steel Plant,* Vol. 10, Page 230.

The characteristics, uses, physical properties, and heat treatment of wrought iron, malleable iron, grey iron, and semi-steel are covered primarily for the benefit of the designing engineer. Photomicrographs illustrating the effect of heat treatment are included.

NEW ALUMINUM ALLOYS OF HIGH STRENGTH. Anon. *Chemical and Metallurgical Engineering,* Vol. 26, Page 689.

The material presented is taken from the Eleventh Alloys Research Report of the Institute of Mechanical Engineers. Tests at temperatures up to 350 degrees Cent. show that an aluminum alloy containing copper, nickel, and magnesium has the best possibilities for pistons. Data is also given on alloys suited for rolling, forging and extruding. As a result of investigations on the influence of heat treatment it is stated that the compound Mg_2Si is responsible for most of the hardening produced on aging quenched aluminum alloys.

METALLOGRAPHY AND CRYSTAL STRUCTURE

THE EFFECT OF IMPURITIES ON RECRYSTALLIZATION AND GRAIN GROWTH. By C. J. Smithells. Presented at the March Meeting of the British Institute of Metals.

To account for the results obtained in an investigation on the influence of soluble and insoluble impurities on the recrystallization of tungsten, the author postulates that the vapor pressure of the individual crystals is the controlling force. On this basis recrystallization takes place by a process of distillation, the atoms going from a crystal of higher vapor pressure to one of lower vapor pressure. The effect of grain size, heat gradients, and strain gradients are interpreted on this basis.

DETERMINING COEFFICIENT OF EXPANSION WITH A METALLURGICAL MICROSCOPE. By H. C. Knerr. *Chemical and Metallurgical Engineering,* Vol. 26, Page 644.

A method for determining the coefficient of expansion of a substance, using only equipment available in nearly any metallurgical laboratory is described. Substances of known coefficients of expansion are placed on each side of the specimen and pined at one end. Hair lines are ruled across the three pieces at each end while the pieces are at a known temperature. Changes in the positions of these hair lines are then noted by means of an inverted microscope, the specimens resting on the glass bottom of a thermostat.

THE STRUCTURE OF WHITE-HEART MALLEABLE. By Rudolf Stotz. *Foundry,* Vol. 50, Page 286.

White-heart malleable consists of an outer layer of ferrite which may contain some pearlite and an inner core composed of graphite, ferrite, pearlite, and some-

times cementite. The tensile strength is about 5200 pounds and the elongation 4 per cent. Numerous photomicrographs illustrate the influence of varying amounts of carbon, sulphur, and of over-oxidizing are shown.

THEORY OF THE HEAT TREATMENT OF STEEL—III. By W. M. Mitchell. *Forging and Heat Treating,* Vol. 8, Page 162.

The effect of quenching in various media (brine, water, oil, and the air blast) is discussed and the proper temperatures for varying amounts of drawing are given. In considering the heat treatment as a whole the previous treatment of the metal must be given consideration.

TENACITY AND TENSILE STRENGTH. By F. Korber. *Stahl und Eisen,* Vol. 42, Page 365.

In case of plastic deformation the increase in strain is proportional to the decrease in cross section. A formulae is given by which the tensile strength may be calculated from the constants of the line equation for the change in deformation with change in tension. The influence of the form of crystal structure on the degree of deformation is studied by means of x-ray spectrographs.

PROBLEMS OF DESIGN AND FABRICATION

PERFECTING A DROP FORGING. By J. H. G. Williams. *Forging and Heat Treating,* Vol. 8, Page 152.

The forged portion of a mechanic's square is taken as an example. Instances of how "cold shuts", "laps", and "mismatches" may occur are illustrated with photographs and the remedies discussed.

HARDNESS TESTING ON A COMMERCIAL SCALE. By E. F. Lake. *Iron Age,* Vol. 109, Page 913.

The difficulties encountered in the commercial inspection of automobile pistons and connecting rods are enumerated and the conclusion is drawn that some method of testing other than Brinell hardness might prove more satisfactory on these articles.

WEAR ON VARIOUS AUTOMOBILE GEAR STEELS. By E. R. Ross. *American Machinist,* Vol. 56, Page 72.

The object of the investigation was to determine the best material for automotive transmission gearing, resistance to wear being used as a basis. The tests reported were on S. A. E. 2345 steel. Slight differences in carbon content notably influenced the wear. Wear on the gear cutters was also found to promote deterioration of the gears.

LEAD HARDENING FURNACES FOR HEATING HAMMERS AND HATCHETS. By G. T. Straub. *Forging and Heat Treating,* Vol. 8, Page 160.

A lead pot installation for hardening hatchets and hammer heads is described. The outfit is equipped with a preheating chamber to utilize waste heat and this also serves as a means of producing charcoal for the lead pots from waste hickory handle blanks.

THE DEPENDABILITY of CAST IRON WELDING. By G. O. Carter. Paper presented before the Cleveland Section of the American Welding Society.

Welded grey iron castings may be depended upon provided the broken parts are properly preheated previous to the welding operation and subsequently allowed to cool slowly. Examples of welded cylinder blocks, die press frames, etc., are discussed and illustrated.

TOOL STEEL

SELECTION AND HEAT TREATMENT OF TOOL STEEL. By S. C. Spaulding. *Blast Furnace and Steel Plant,* Vol. 10, Page 224.

The points to consider in selecting a tool steel are (1) ease of fabrication, (2) permissible dimentional changes on hardening, (3) ease of hardening, (4) nature of service to which tool will be put (heavy or light cuts), (5) nature of material to be cut by tool, (6) temperature of material to be cut, and (7) amount of production expected from the tool. Proper methods of heating, quenching, and tempering tool steels are discussed in a very general way.

ELECTRIC TOOL STEEL MELTING PRACTICE. By W. J. and S. S. Green. *Iron Age,* Vol. 109, Page 999.

In tool steel melting where refining plays no part in the operation, basic bottoms are recommended. Cold charges are to be preferred to molten metal. Double voltages of 115 to 125 high and 75 to 85 low have been found to give satisfactory results.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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CHANGES OF ADDRESS

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ARTHUR, J. E., (M-12)—from 36 Rhodes Ave., S. Charleston, W. Va. to Box 667, Midland, Pa.

BARNES, CHAS., (M-3)—from 2009 S. 23rd St. to 1933 McKean St., Philadelphia, Pa.
BARR, Wm. JR.—from Hughes Tool Co., Houston, Texas to Hughes Tool Co., Los Angeles, Cal.
BONNING, F. W., (M-1)—from the Cummings Co., Boston, Mass. to 288 Broadway, Malden, Mass.
BROWN, F. D., (M-2)—from 6014 Belvidere Ave., Cleveland to Antrim, N. H.
BRUA, G. E., (M-10)—from Rock Island, Ill. to 353 E. Orange St., Lancaster, Pa.

COX, A. M.—from R. D. Nuttal Co. to Pittsburgh Commercial Treating Co., 7143 Frankstown, Pittsburgh, Pa.

DAMICO, A., (M-5)—from 1744 E. Passyunk Ave. to 729 Pierce St., Philadelphia, Pa.
DARFLER, R. W., (M-3)—from 209 Lewis St., to 337 Collins St., Blue Island, Ill.
DAVIS, F. G., (A-10)—from 1437 Franklin St., E., to 2444 Grand Blvd., Detroit.
DAVIS, T. L., (M-2)—from Woodward Governor Co., Rockford, Ill.
DIETZMAN, H. M., (M-3)—from 615 Collings Ave., W. Collingswood, N. J. to 34 Congress Rd., Lakewood, N. J.

FELKER, A. W., (A-2)—from 1598 Elbur Ave., Lakewood, Ohio, to Crucible Steel Co. of America, 1723 Lafayette Blvd., Dettroit, Mich.
FITZGERALD, M. V., (M-2)—from 691 State St., to 89 Linden St., Springfield, Mass.
FLANNERY, W. R., (A-4)—from 2849 Equitable Bldg., New York City to 849 Book Bldg., Detroit, Mich.

GEISSINGER, H. C., (A-4)—from 411 Kresge Bldg. to 6337 Charlevoix Ave., Dettroit.
GRAHAM, W. F.—from Truell Court, Plainfield, N. Y. to Y. M. C. A., Hartford, Conn.

HANDY, H. E., (M-3)—from 173 Elmwood Ave., Providence, R. I. to Saco-Lowell Shops, Lowell, Mass.
HERB, J. W., (M-2)—from 416 Ferry St., to 729 Washington St., Easton, Pa.
HODGE, J. E., (M-5)—from 1921 Irving Ave. S. to 1760 Hennepin Ave., Minneapolis.

JACKMAN, E. T., (A-2)—from 85 W. First St., Boston, Mass. to 710 W. Lake St., Chicago.
JENKS, W. E., (M-3)—from 2166 DeForest Rd. to 11417 Continental Ave., Cleveland.

KELLY, J. N., (M-4)—from 275 Caroline St., Derby, Conn. to Care Higley Machine Co., S. Norwalk, Conn.
KERR, CHAS. A. T., (M-12)—from 21 W. 16th St. to 2107 N. Penn, Indianapolis.
KOEHLER, CHAS., (M-9)—from 78 Grove St., to 72 Freeman St., Hartford, Conn.

LANNON, J. D., (M-4)—from 389 Tuxedo Ave., Detroit, to 8 Glenwood Ave., Pontiac, Mich.
LANGHAAR, L., (M-4)—from Langhaar Ball Bearing Co. to 311 Cottage Ave., Aurora, Ind.
LARNED, Elmer, (M-5)—from Interstate I. & S. Co., E. Chicago, Ind. to Interstate Iron & Steel Co., 104 S. Michigan St., Chicago.
LEVY, W. J., (M-9)—from 5939 S. Elizabeth St. to 6152 S. Aberdeen, Chicago.
LICKTEIG, A. F., (M-4)—from A. C. Gilbert Co. to 14 Fox St., New Haven, Conn.
LIZOU, LEO, (M-12)—from 1372 Richard St. to 767 55th St., Milwaukee, Wis.
LOVE, W. D., (A-2)—from Atlas Crucible Steel Co., Philadelphia to 1437 Franklin Street, Detroit, Mich.
LOWRY, J. E.—from Coliver Chilled Plow Wks., to Box 248, South Bend, Ind.

MANN, R. L., (M-5)—from Tate-Jones & Co. to 37 Allen St., Buffalo, N. Y.
MERICA, P. D., (M-11)—from International Nickel Co., Bayonne, N. J. to Development & Research Department, International Nickel Co., 67 Wall Street, New York City.
MILLER, S. W., (M-10)—from 349 Orchard St., Rochester, N. Y. to Union Carbide & Carbon Research Lab., Long Island City, N. Y.
MULL, E. K., (M-7)—from 107 W. 7th St., Plainfield, N. J. to Room 419, Y. M. C. A. Bldg., Rochester, N. Y.
McCONNELL, J., (A-2)—from 2605 E. 7rd St., Chicago, to United Alloy Corp., Canton, Ohio.

PAFENBACH, C. R., (M-6)—from 66 Walnut St. to 11 Lakeview Pkwy., Lockport, N. Y.
PRICE, J. M., (A-4)—from Electro Sales Corp. to 30 E. 42nd St., New York City.

REDDERSON, E. W., (M-4)—from 935 W. 68th St. to 6909 S. Green St., Chicago.
RODNEY, K. R., (M-4)—from New Castle, Del. to Highland Iron & Steel Co., Terre Haute, Ind.

SADTLER, C. B., (M-1)—from 61 Roslyn Ave., Glenside, Pa. to 1615 N. Meade Ave., Chicago, Ill.
SCHAGRIN, H., (M-12)—from 6 White Ave., S. Charleston, to Care Blumenfeld, 1115 S. Frankfort, Tulsa, Okla.
SHERMAN, P. B. JR., (M-1)—from 2108 E. 96th St., Cleveland to Room 608 Y. M. C. A., Canton, Ohio.
SKOOG, C. F., (M-12) from 711 E. Harvey St. to 2510 Erskine Blvd., South Bend.
SMART, C. F., (M-3)—from 1617 Holden Ave., Detroit to Oakland Motor Car Co., Pontiac, Mich.
STEVENSON, C. M., (A-12)—from Colonial Steel Co., Toledo, Ohio to P. O. Box 645, Pittsburgh, Pa.

TAYLOR, JAMES, (M-1)—from 312 3rd St., Scotia, N. Y. to 120 Degraff St., Schenectady, N. Y.

WEED, H. C., (A-4)—from 4654 N. Monticello Ave. to 4737 Lawndale Ave., Chicago.
WHITEHEAD, SGT. W. F., (M-3)—from Camp Pike, Ark. to Q. M. C., Manila, P. I.
WILLIAMS, R. L.—from Crucible Steel Co. ot Lenox Hotel, Detroit, Mich.
WOODWARD, A. F., (M-4)—from 432 Hawkins St., Cincinnati to 1483 E. 65th St., Cleveland, Ohio.

MAIL RETURNED

ASKEW, HARRY J., Jr., Crucible Steel Co. of America, Detroit, Mich.

FULLER, E. C., 341 Endicott Bldg., St. Paul, Minn.

GAUGHAM, E. J., 2722 N. 28th St., Philadelphia, Pa.

HALTER, J. L., (M-12), 8 White Ave., S. Charleston, W. Va.

PYNE, J. E., (M-4), Diamond Alloy Tool Co., St. Louis, Mo.
ROSE, HANS, Noroton Heights, Conn.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

STANDING OF THE CHAPTERS

In the May issue of the TRANSACTIONS was published the standing of the chapters as of April 1st. The list below shows the standing of the chapters on May 1st.

1. Chicago	11. †*Syracuse*	21. Schenectady
2. Detroit	12. †Milwaukee	22. New Haven
3. PITTSBURGH	13. WORCESTER	23. *Washington
4. *Philadelphia*	14. CINCINNATI	24. *Buffalo
5. Cleveland	15. **North West*	25. Toronto
6. New York	16. **Rockford*	26. South Bend
7. HARTFORD	17. Tri City	27. Rochester
8. *Indianapolis*	18 SPRINGFIELD	28. Bridgeport
9. BOSTON	19. PROVIDENCE	29. Gary
10. LEHIGH VALLEY	20. *St. Louis*	
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The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on April 1st. Those shown in italics are not occupying as high a position as in the previous report.

Pittsburgh continued its stride during the month and passed another chapter. At the present time it occupies position No. 3 and has served notice that within a short time it expects to occupy position No. 2.

The tie last month between Hartford and Indianapolis resulted in favor of Hartford and that chapter is occupying No. 7.

All members of the Society should give the above report very care-

ful consideration and should lend every effort to advance the positions of their chapters.

Many of the chapters are separated but by a few members and an increase of only a small number would serve to make a radical rearrangement of the whole list.

BRIDGEPORT CHAPTER

The Bridgeport Chapter held its April meeting on Friday, the 21st in the Camber of Commerce rooms. This was the annual meeting of the year in which the report of the secretary and treasurer was made and the election of officers for the coming year. H. T. Dow was elected chairman; E. M. Hays, vice chairman; and C. F. Schmelz, secretary-treasurer. E. B. Crocker, H. M. Ellsworth and L. F. Schwerdtle were elected members of the executive committee.

The program for this meeting consisted of four reels of moving pictures taken at the plant of the American Sheet & Tin Plate Company entitled "Manufacture of Steel for Sheets & Plates," which covered all of the operations from the ore to the shipping of the finished plate. Following these pictures a comedy reel was exhibited.

About 75 members and guests attended this meeting.

PITTSBURGH CHAPTER

The annual meeting of the Pittsburgh chapter was held May 1st at which time Dr. Unger gave a very interesting and instructive talk entitled "The Need for More Practical Information in Industry." This paper was very well received and proved to be of vital interest to steel treaters. The annual report and election of officers was held at this meeting. The officers for the ensuing year are as follows:

N. B. Hoffman, Colonial Steel Company—Chairman; W. J. Merten, Westinghouse Electric & Mfg. Company—vice-chairman; D. W. McDowell, secretary-treasurer. The following members of the executive committee were elected; C. M. Johnston, Crucible Steel Company of America; Geo. Loefler, Carbon Steel Company; A. M. Cox, Pittsburgh Steel Treating Company; Frank Garrett, Latrobe Steel Company; S. L. Goodale, University of Pittsburgh; W. H. Phillips, R. D. Nuttall Company; Prof. F. M. Crabtree, Carnegie Institute of Technology; D. H. Horne, United Chemical Company; B. D. Sachawalla, American Vanadium Corporation; W. Buechner, E. F. Houghton; W. B. Crowe, Carnegie Steel Company.

SOUTH BEND

The South Bend chapter held its annual meeting May 9th at Kables Banquet Hall. The meeting was preceded by a dinner attended by 33. At this meeting the following officers were elected unanimously: J. A. Kingsbury, chairman; W. F. Newhouse, 1st vice-chairman; C. B. Peterson, 2nd vice-chairman; S. Shagaloff, secretary-treasurer.

Mr. W. J. Harris was elected chairman of the membership committee.

Following the election Mr. C. L. Richie read a paper on "The Recent Advances made in Heat Treatments," and Mr. A. E. Tarr of the Leeds & Northrup Company gave a talk on "Electric Furnaces".

Regular meetings of the chapter were adjourned until September 12th, due to warm weather.

WASHINGTON CHAPTER

At the April meeting of the Washington Chapter, held on the 21st in the auditorium of the Interior Department Building, National President, Frank P. Gilligan, presented a paper on "The Influence of Quality from the Standpoint of Workmanship and Material." An unusually clear explanation of the iron-carbon diagram and its application in the heat

H. J. French, re-elected chairman, Washington Chapter.

Alexis Caswell, re-elected secretary-treasurer of North West Chapter.

treatment of various carbon steels was first presented after which a large number of failures in service were shown and the methods of determining their causes explained in considerable detail.

Among the interesting items was a comparison of methods used by what might be called the "two schools in heat treatment," namely, that favoring high temperatures for short times vs. that advocating the use of lower temperatures for relatively long periods in normalizing and breaking up refractory structures. The value of the fracture test and macroscopic etching for inspection of steel and in determining causes of failure was also clearly shown.

Mr. Gilligan's paper was unanimously declared to be of exceptional merit and interest and following its presentation a short but lively discussion was undertaken by the members present.

On Monday, May 22, the Washington Chapter held its regular meeting at which Professor Haakon Styri, Director of Research of the S. K. F. Laboratories, Philadelphia presented a very interesting paper entitled "Preparation and Heat Treatment of Ball Bearing Steels". In

this paper he discussed the preparation of high grade alloy steels for manufacturing ball bearings and bearing parts. He laid considerable stress on the point that great skill and experience is required in handling these steels. Heat treating and hardening steels for automotive bearing purposes were thoroughly discussed by Prof. Styri.

The laboratory with which Prof. Styri is connected has devoted a great deal of attention and study to the proper quenching temperatures and the proper rate of cooling of these steels.

The speaker's experience in this work combined with illustrations of the results he has obtained were exceedingly interesting.

A lively discussion followed this paper which was of benefit to all.

NEW YORK CHAPTER

The May meeting of the New York Chapter was held in the Assembly room of the Merchants Association in the Woolworth Building, Wednesday, May 17.

The program for this meeting was a paper presented by C. M. Blackman, Foreman of the hardening departmnt of the Colt's Patent Fire Arms Mfg. Company, Hartford, entitled "The Heat Treatment of High Speed Steel".

Mr. Blackman is a man who has had many years practical experience in the heat treatment of steel and discussed his subject from a practical stand-point rather than the technical. He brought out many points of interest to tool hardeners as evidenced by the interesting discussion which followed his paper.

The election of officers for the ensuing year took place at this meeting. They will be announced later.

ROCKFORD CHAPTER

The Rockford Chapter held its regular May meeting Wednesday the 10th. Mr. James P. Gill, Metallurgist, Vanadium Alloys Steel Company, Latrobe, Pa., presented a very interesting paper entitled, "High Speed Steel". He discussed very thoroughly its manufacture, heat treatment and its metallography. Mr. Gill has devoted a number of years to the research of high speed steel and handled his subject in a very comprehensive manner. A very interesting discussion followed Mr. Gill's paper and much valuable information was obtained by those present.

Election of officers for the ensuing year was held after Mr. Gill's paper.

CHICAGO CHAPTER

Chicago Chapter held a meeting, Thursday evening, May 11 at which time, Mr. James P. Gill, Metallurgist, Vanadium Alloys Steel Company, Latrobe, Pa., presented his very capable paper entitled "High Speed Steel." In presenting this paper Mr. Gill included information as to the manufacture, working, heat treatment and metallography of high speed steel. Mr. Gill has done a great deal of research work on high speed steels and was able to present some very interesting data on the recent developments of this metal. An interesting and instructive discussion followed this paper.

PHILADELPHIA CHAPTER

The April meeting of the Philadelphia chapter was held on the 28th at the Engineer's Club, and a very interesting program of motion pictures was exhibited.

Mr. T. H. Nelson, Steel Works Manager of the Henry Disston & Sons Company, and Mr. W. S. Stephenson of the American Rolling Mill Company lectured, with movies showing the triplex process of the manufacture of ingot iron. The story of ingot iron was depicted very clearly with reels showing the methods used in the manufacture of pure iron and illustrated the latest approved methods of the manufacture of iron and steel.

To close the program a reel of comedy pictures were shown.

D. W. McDowell, reelected secretary-treasurer Pittsburgh Chapter.

J. E. Rogers, elected chairman of Worcester Chapter.

RHODE ISLAND CHAPTER

The May meeting of the Rhode Island Chapter was held on the 3rd of the month. A very interesting paper entitled "Inspection and Testing of Raw Materials and Heat Treated Parts for Automobiles to Insure Standing up in Service," was delivered by Mr. R. J. Allen, Metallurgist of the Rolls-Royce Company of America, Springfield, Mass. Mr. Allen who is vice president of the National Society, is an authority on steels and their proper heat treatment for use in the automotive industry. This paper was very well delivered and proved to be intensively interesting as evidenced by the large amount of discussion which followed.

Mr. R. H. Schafer, Supt. of the Textile Finishing Machinery Com-

pany, Providence, was elected chairman, while Mr. F. H. Franklin, of Oleyville, R I. was elected vice chairman for the coming year.

ST. LOUIS CHAPTER

The chapter held its May meeting on Friday evening, the 12th at the plant of the St. Louis Pressed Steel Company. The meeting consisted of an inspection trip through this plant. Mr. Key acted as guide

John E. Halbing, reelected chairman Lehigh Valley Chapter.

Albert P. Spooner, reelected secretary-treasurer Lehigh Valley Chapter.

and explained the main points of interest throughout his plant. Following this trip of inspection which proved very interesting and instructive, the chapter held a short meeting at which time the election of new officers took place.

SYRACUSE

The Syracuse chapter held its regular meeting May 5th at which time the officers for the ensuing year were elected. They are as follows: W. F. McNally, Chairman—New Process Gear Corporation, Syracuse; R. F. Smith, Vice-Chairman—E. F. Houghton Company, Syracuse; A. G. Carman, Secretary-Treasurer—H. H. Franklin Mfg. Company, Syracuse. The following executive committee officers were elected: H. J. Stagg—Halcomb Steel Company; S. C. Spalding—Halcomb Steel Company; Frank Singer—Syracuse Twist Drill Company; C. E. O'Connor—Sanderson Steel Company; Wallace Marriott— New Process Gear Corporation.

WORCESTER

The Worcester chapter held its annual banquet and meeting at the Boston Store restaurant on March 20. There were 95 present among whom were the leading executives of all of the metal working industries in Worcester.

The speakers for this meeting were our National President, F. P. Gilligan whose remarks were of a general nature; Dr. John A. Mathews who presented his paper on "Iron in Antiquity and Today"; Mr. N. R. O'Hara, humorist of the Boston Post, New York World, Life, and Judge, entertained the members for about 20 minutes with some very humorous sketches for which he has made a name throughout the country.

Following the speakers of the evening, the election of officers took place. They are as follows: J. E. Rogers, A. Hankey & Company, Rochdale, Chairman; W. A. Bacon, Reed-Prentice Company, Worcester, Secretary-Treasurer. The members of the executive committee are as follows: V. E. Hillman, Crompton & Knowles Loom Works, Worcester; George C. McCormick, Crompton & Knowles Loom Works; John C. Spence, Norton Co., Worcester; Philip Knowles, Walden-Worcester, Inc., Worcester, Mass.

Mr. Hillman in closing the year gave a very timely address on the advances which the Worcester Chapter had made and its prospects for the future. Many gratifying remarks were made to the members who were thanked for their enthusiasm in assisting with the work and purposes of the Society.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held its regular monthly meeting, May 29 at Easton Public Library at which time, Mr. B. H. Delong and Mr. R. W. Zimmerman delivered a paper entitled "Physical Testing." This paper was very instructive and was well received by those who were present.

ROCHESTER CHAPTER

On May 10th the Rochester Chapter held its regular monthly meeting. Mr. R. E. Talley of the Geo. J. Hagan Company delivered a very interesting paper entitled "Electric Furnaces for Heat Treating Purposes." As the electric furnace is coming into use more and more this topic proved of great interest to those who had the pleasure of hearing Mr. Talley.

DETROIT CHAPTER

The Detroit Chapter held its May meeting on the 8th in the Board of Commerce Building at which time Mr. Henry Voltmann of the W. S. Rockwell Company presented his paper entitled "Methods of Heating and Handling." Mr. Voltmann's paper contained very valuable information and was well received by the membership. His discussion of design and fuels were of prime interest.

The last meeting of the season for the Detroit Chapter was held on

May 22 in the Board of Commerce Rooms at 8 o'clock. The paper for this meeting was presented by Guy Baldwin of the Bruce Products Company entitled "Review of Metal Cleaning Process and Equipment". This paper was very interesting in that it dealt with the cleaning of metals prior to subsequent treatment.

The election and installation of officers was held at this meeting. They will be announced later.

BOSTON CHAPTER

Boston Chapter held its last meeting of the season on Friday, May 26th at the Boston City Club. The meeting was preceded by a dinner served at 6:45.

The annual meeting and election of officers was held after which the speaker of the evening, Mr. J. C. Spence of the Norton Company presented a very interesting paper entitled "Grinding Practice". Mr. Spence's paper was very instructive inasmuch as considerable difficulty is experienced in the production of hardened parts which are subsequently ground, resulting in grinding cracks. These cracks are usually due to the improper selection of grinding wheels. An interesting discussion following Mr. Spence's paper was held which revealed many points of information to those present.

HARTFORD CHAPTER

The Hartford Chapter of the American Society for Steel Treating accepted the very kind invitation of Vice-President Hughes of the New Departure Manufacturing Co., to visit their plant at Bristol on the chapter's annual visitation trip Saturday, April 29.

The Hartford Chapter invited the New England chapters of the American Society for Steel Treating and also the New England sections of the Mechanical Engineers to visit with them. About 300 accepted and spent a very pleasant day at Bristol.

The guests began to arrive about 9 o'clock and were divided into groups of 15 to 20 and under the direction of guides from the New Departure staff, made a circuit of the entire plants, having the places of interest pointed out to them. A rather complete discription of this trip of inspection is given in the following pages. At the conclusion of this trip of inspection, the visitors partook of a buffet luncheon served in the cafe of the inn.

After the luncheon, the guests and members visited the Administration building and proceeded thence to the Endee Club where the program of the afternoon was conducted.

Mr. Marcus E. Gere, chairman of the Hartford Chapter welcomed the guests in the name of the Hartford Chapter and called upon Vice-President Hughes who extended a word of cordial welcome on behalf of the New Departure Co. Mr. Hughes outlined briefly, the history of the organization and the progress it had made in the last few years when it had grown from a small industry to one employing over a thirty million dollar capital; stating that the reason for the increase in growth was because

they had applied to their business, principles of honesty of purpose and honesty of execution.

Pres. Frank P. Gilligan of the National Society replied to Mr. Hughes' words of welcome and expressed appreciation for the many courtesies extended. Mr. Gilligan then served as chairman of the meeting and called

Members and guests of the Hartford Chapter who attended the trip of inspection meeting through the New Departure Mfg. Co's., plant at Bristol, Conn.

upon National Secretary, W. H. Eisenman to give a few remarks on "Heat Treating the Executive." The speaker brought out particularly the necessity for excellent working conditions, modern equipment and methods, so that progress would be made in the science of heat treatment.

The principal address of the afternoon was given by Prof. H. F. Moore of the University of Illinois, who presented his interesting and entertaining lecture on the "Fatigue of Metals," illustrating it with lantern slides and moving pictures. Prof. Moore's paper was exceptionally well received and proved a suitable climax to a most interesting day.

Before the meeting adjourned the following resolution was presented by Mr. Blackburn of the Hartford Chapter and unanimously adopted: "Resolved that all present extent to Vice President Hughes and his excellent staff of the New Department Mfg. Co., our hearty thanks for the many courtesies and the generous hospitality extended to us by our hosts.

That we especially convey our thanks to the committee of the New Departure Company consisting of Mr. C. B. Simmons, T. C. D. Crow and M. E. Gere, for the excellent arrangements for the reception and entertainment of us while at the plant and that we also extend our thanks to Mr. James J. Curran, L. A. Lanning and M. E. Gere, the committee of arrangements of the Hartford Chapter, for their efficient work in preparation of this notable event."

The New Departure Company gave as souvenirs to all those in attendance a 200-page booklet entitled "Ball Bearings in Industry" which had a two-page insert giving views of the plant the visitors had inspected. *The New Departure News* published by and for the employes of the New Departure Co., was placed in the hands of each member and especialy note-worthy was the editorial entitled "Our Guests Today" written by Mr. D. Page the editor in chief, which was as follows:

"Our guests today, members of the American Society for Steel Treat-

ing and American Society of Mechanical Engineers, will receive this copy of *The New Departure News* right from the press of our printing department. In its columns they will find reflected something of the New Departure spirit of industrial comradeship, loyalty, co-operation, and pride in both plant and product.

We extend a welcome to our guests in that same spirit and trust that their brief stay with us may prove to be not only interesting but helpful. It is a fine satisfaction to know that our work counts for constructive progress, that the results we attain are builded into development and improvement of invention and genius, that we are right-handed fellows, working each in his particular field, but all impelled by the same motive, to wit., establishing and maintaining world surpassing efficiency, principle, and method in American industry.

If there is one aim that is ahead of all others in the minds and work of New Departure employers and employes, it is this, that our product shall be unexcelled. The sincerity of that purpose you have undoubtedly sensed as you have passed through the plant and listened to what has been said concerning that which you have seen.

So our welcome is that of kind to kind, plus the cordiality and sincerity that is born of high respect for your organizations and your work as individuals."

TRIP OF INSPECTION THROUGH THE NEW DEPARTURE PLANT

The Forge plant was the first section visited. It is located nearly ½ of a mile from the main plant on one of the few comparatively flat lands in the vicinity of Bristol, adjacent to the railroad with which it has excellent connections. Our party arrived at the east end of the bar alley of the forge plant and viewed

Airplane view showing main office and works of the New Departure Mfg. Co. plant at Bristol, Conn.

the buildings on the right which are used for the general storage of material for consumption in the entire Bristol plant, where the material is received and unloaded from freight cars and stored. The forge shop proper is shown in Fig. 1. The bar shed which is 75 feet by 275 feet is of all steel construction equipped

with a crane for the unloading of bars direct from cars and facilities for storing and delivering the material to the forging operations in the shop across the way. The forge shop was especially designed under direction of the New Departure engineers and erected in 1919 and 1920. The building is 125 feet by 475 feet and is equipped with 35 large forging machines, many of them weighing upwards of eighty tons each. There are a few drop hammers used for the drop forgings of bicycle coaster brake parts and other similar work.

The forging operation is carried on by heating the bar in specially designed furnaces and upsetting it in dies by end-wise pressure, thus end-wise forging the bar which has hitherto been hotworked entirely in a longitudinal direction. A collar is raised up on the end of the bar in the fiirst operation, punched off in the second and the ring is completed. The steel used is electric furnace high carbon chrome steel, containing 1.05 per cent carbon and 1.65 per cent chromium, phosphorus and sulphur below 0.03 per cent. The buttends or tong holds remaining after the forging operation has been completed on large bars is carefully saved, reheated and rerolled into smaller sizes of bar in a three-high two-stand rolling mill. The hardening shop is arranged for the most efficient treatment of high alloy steels of high speed or similar nature used for the manu-

Fig. 1—Forge Plant. The largest plant in the East using the upsetting type of forging machine.

facture of dies. It was interesting to note the completeness of the installation and that all furnaces, with the exception of the two electric furnaces, were of New Departure design and construction.

In the die department dies are manufactured for use in the forge shop. The building is arranged in two heights, the smaller or belt machinery being grouped under the lower part and the heavier machinery in the higher part of the building. Great pains were taken to provide all facilities and the most modern sanitary arrangements for the convenience of the workmen.

The plant manager's offices were at the end of the building, while on the second floor the accounting and drafting departments were located. It is interesting to note that in the forge plant no artificial ventilation is required, there being sufficinet movable glass in the roof to be equivalent to the removal of half the roof.

MAIN PLANT

The party then followed the route of the forgings. Arriving at the main plant they entered the annealing building. The forgings are first normalized in the furnaces of a standard type. After normalizing the forgings are annealed in

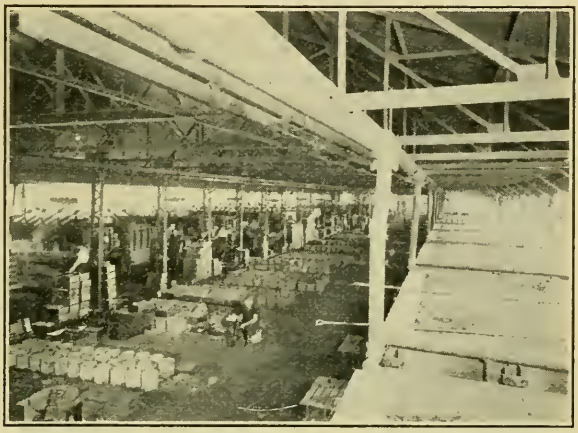

Fig. 2—Main Heat Treating Department. Plant A.

the 53 furnaces in this department. Two large pots containing forgings are loaded by the over-head crane. Each furnace charge consists of approximately two tons. The annealing of the high carbon chrome steel for proper metallurgi-

Fig. 3—Ball Plant. The largest steel ball plant in the world. Daily capacity 20,000 pounds of high carbon chrome steel balls, ranging in size from ⅛ to 2 inches in diameter.

cal properties requires the greatest care and the utmost accuracy in furnace design and control. In these furnaces from 100 to 150 tons of steel are constantly undergoing the annealing operation.

After annealing, the forgings are sent to be pickled in the pickling room.

Departing from the route of the forgings for a moment, the heat treating operations on the finished machined pieces was inspected. This department is shown in Fig. 2. In this building are the hardening and carburizing furnaces, all of New Departure design. The small loss of heat from these furnaces was due to the excellent insulation. The rings are strung on wires of which a standardized quantity is introduced into each furnace and heated for a standardized time in comparison with the pyrometer at the end, and then quenched in tanks of agitated quenching oil. The work to be quenched falls upon an oscillating grid by means of which it is automatically agitated and any possible chance of human laxity eliminated. The control of the furnace fire is not in the hands of the operator but is controlled by operating foreman called firemen who regulate furnace temperatures in accordance with what the pyrometer signals. The carburized work coming from the furnaces is handled mechanically and cooled in a shed on the left. After dumping, the empty pots travel to another building on the right and are repacked. Only coaster brake parts and certain parts of bearings are carburized, the vast majority of parts being made of hard high carbon steel.

Instead of the work being tempered in oil as heretofore, they have worked out a novel application of electric heat in the tempering oven. The work to be tempered travels back and forth through the oven the tempering being effected by heated air, automatically circulated and automatically, pryometically

Fig. 4—Interior of Semi-Final Grinding Department. Plant A.

and electrically controlled. The maximum variation from fixed temperatures in any part of the furnace does not exceed three degrees.

The testing laboratory occupies the whole front of a building of three floors. The chemical laboratory is arranged for the most economical handling of their particular problems while the metallurgical laboratory is provided with all the usual and some unusual equipment.

Some years ago New Departure engineers and metallurgists developed a process by which high carbon chrome tool steel can be so treated as to be made into the strongest possible ball by a cold forging process. This entails an enormous outlay for annealing and treating plants, as well as a wire mill, and upon these prior operations the greatest of care is expended. This building which is under construction will be largely a duplicate of the annealing building just described, adapted for the annealing of large sized wire and rods. After annealing of the wire which is done in the presence of carbonaceous material to prevent decarbonization, soft spots and reduce scale, it is pickled in concrete pickling tanks. The wire is then pointed so that it may enter the drawing dies. In these machines pointed wire is inserted and reduced by be-

ing drawn through dies. After drawng, the wire is suitably stiffened and is re-annealed to make ready for the grinding operation. The ground floor of this building is interesting in that it contains considerably over two acres, is 220′ wide x 460′ long and the entire ball plant contains in one building considerably over six acres of floor space.

The fourth floor which covers over an acre in extent is devoted to rough

Fig. 5—Endee Inn. Hotel-Club for employees.

grinding. The machines are continuous and automatic. The balls, in lots, as they come from the first operation proceed through all succeeding operations in lots of approximately 250 pounds each. The grinding is done by means of an abrasive wheel, balls in a stream passing over the face of this wheel are

Fig. 6—Assembly Hall, Endee Club.

ground in the soft state to within a few thousand of finished size. After the rough grinding, balls are normalized and annealed and then hardened. At the present time the hardening shop is on the 4th floor, but is about to be moved

adjacent to the large building. The balls are hardened on flat trays two or four trays to a furnace and quenched in these very deep tanks extending to the floor below.

The finish grinding floor is still in process of reconstruction. It contains upwards of an acre and a half of floor space. Here the hardened balls are lapped continuously and automatically between grooved iron plates between which a thin abrasive compound is passed. After grinding they are wiped with sawdust and fine leather to remove all traces of abrasive in tumbling barrels on the right. On the second floor all balls are given inspection for service perfection. Each perfect ball passes through the hands of five consecutive inspectors and arrives at the perfect grade through the process of elimination of all imperfections. Perfect balls are here gaged for size to ten, thousandths of an inch and sorted into containers all balls in which are maintained to within a limit of one ten thousandth of an inch. Throughout the process and continuously the balls are checked for spheroidty. The limit is an eighth of a ten thousandth of an inch.

The ball plant shown in Fig. 3 is one of the largest if not the largest in the world, containing over six acres of floor space. It has a production of

Fig. 7—The Lounge, Endee Club.

20,000 pounds daily. All sizes are made from ⅛ inch to 2 inches in diameter.

The party then followed the hardened race-rings into the semi-final grinding department, shown in Fig 4. This building is 130 feet wide and approximately 300 feet long given over to the grinding operations on the race rings as parts before the introduction of the balls and the assembly of the bearing. The first operation is surface grinding, then internal grinding, then oscillation of race groove. Inner races are bore ground. Every operation is followed by inspection to the highest accuracy conceivable. A large shop is given over solely to the manufacture of gages.

The Endee Inn, shown in Fig. 5, Fig. 6 and Fig. 7 is an employee's hotel built to house 314 men and as assistance to the housing facilities to meet the company's operations in Bristol. The company is also an extensive builder of houses and owns in whole or in part upwards of seven hundred houses which it has been instrumental in erecting in the last few years.

In three factories the company employs a capital of upwards of $30,000,000.00 and in normal operating times they have ten thousand employees with a daily production capacity of 60,000 bearings and 3000 coaster brakes. Two other plants are maintained, one at Hartford for manufacture of small bearings with a capacity of 20,000 bearings per day. A new plant has recently been erected in Meriden, Conn., destined to have a productive capacity of 20,000 bearings per day. At this plant in Bristol another 20,000 bearings a day can be produced, as well as all the forging, the major part of the heat treating and all the ball manufacture.

Commercial Items of Interest

UNITED States Civil Service Commission, Washington, D. C. announces open competitive examinations for Federal civil service in which many chemists, metallurgists and heat treaters will be particularly interested. The positions which are now open and for which these examinations will be given shortly are, Laboratorian—Chemical, Physical and Engineering; Laboratory Assistant—Junior Grade; $1000.00 a year and Senior Aid $900.00 a year. Those interested in these examinations may obtain full information regarding them from the Civil Service Commission, Washington, D. C., or the secretary of the civil service board at the post office or custom house in any city.

Howard E. Handy, formerly Assistant Metallurgical Superintendent of the Washington Steel & Ordnance Company has been appointed Metallurgist for the Saco-Lowell Shops, Manufacturers of Textile Machinery, at Lowell, Mass. Prior to going to Washington, Mr. Handy was associated with the American Locomotive Company as Assistant Engineer of Tests.

The Fahy Experimental Permeameter developed by Frank P. Fahy is described in bulletin 990 published by James G. Biddle, of Philadelphia. This bulletin discusses magnetic measurement, going into more or less detail on the physical aspects of the subject describing in some detail on the on the physical aspects of the subject describing in some detail various physical terms. It then discusses the Fahy Experimental Permeameter and its application to the tests of materials for their magnetic properties.

The Detroit Twist Drill Company has inaugurated a technical service department which is compiling valuable information for the engineer. This information is being distributed in bulletin form on standard 8½ x 11 loose leaf note book paper, which makes it possible to be inserted in a loose leaf binder for ready reference. These bulletins cover such items as the discussion of the advantages of ground wire drills; the modern high speed drill and the Detroit expansion hand reamer; the taper bridge reamer, etc. Each of the topics are illustrated and handled in a very comprehensive manner including considerable detail of design and method of manufacture.

The Iron and Steel Institute held its annual meeting Thursday and Friday, May 4th and 5th, 1922 in London, England. A very interesting program had been arranged covering some very valuable new information covering recent researches in iron and steel.

The Metal & Thermit Corporation, 120 Broadway, New York City announces the removal of its Pittsburgh branch office from 1427 Western Avenue to 801-807 Hillsboro Street, Corliss Station, Pittsburgh, Pa.

(*Continued on Page* 34)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING, Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

ENGINEERING or PRODUCTION WORK—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired $200-$250. per month. Address 5-25.

SALESMAN—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

METALLURGIST—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired $4500. per year. Address 5-35.

SUPERVISOR HEAT TREATING—Or assistant Ten years experience as chemist on iron and steel. One year practical experience on metallurgical inspection directly connected with heat treatment. Have made a study of the subject. No preference as to location. Wages $40.00 per week desired. Answer 5-50.

FURNACE DESIGNER and BUILDER—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

ASSISTANT METALLURGIST—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired $150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

METALLURGIST AND ENGINEER—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

CHEMIST—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

SALES ENGINEER—Thorough metallurgical training and experienced salesman. At present employed but desires change. Wide acquaintance New York, New England and Canada. Basic knowledge foreign markets and can produce. Age 28. Married. Address 4-5.

METALLURGIST OR CHEMIST—Graduate of Ohio State. Extensive experience covering heat treatment, case hardening, pyrometry, chemical analysis, metallography, and investigation of tool troubles. Best of recommendations. No preference as to location. Address: 4-50.

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

HEAT TREATING DEPARTMENT—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary $150.00. Cleveland location preferred. Address 4-10.

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TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, July 1922 No. 10

SECTIONAL MEETINGS A SUCCESS

JUDGING from the excellent attendance and keen interest which has been shown at the New York and the Pittsburgh Sectional meetings the board of directors is to be complimented for their wisdom and foresight for having established these between convention meetings. Members from many parts of the country were in attendance at each of these two-day sections and many expressions commending the meetings were heard. The large amount of discussion which followed all of the papers which were presented indicates very clearly that a keen interest prevails and that the sectional meetings have become a permanent part of the Society's program of activity. Each of our chapters should be looking forward to the time when they will be the hosts for one of the sectional meetings. It is surprising how much the work of the Society means to everyone especially to those who are preparing and planning a meeting, trips of inspection and entertainment for visitors. It throws the members of a local chapter into a more intimate relationship and cannot possibly result in anything but unbounded success for the individual members, the local chapters and the national Society. May we all look forward to the next sectional meeting which will occur around the first of the next year.

RESEARCH

COMMENDABLE work is being done by the National Research Committee of the American Society for Steel Treating under the able chairmanship of Lt. Col. A. E. White, who has succeeded in having appointed by all of the chapters a local sub-committee on research to serve in an advisory capacity. Among the many opportunities for service to this group of exceptional men is the preparation of a list of subjects and which offer possibilities of research upon which it is desirable to work. The preparation of this list of subjects will be valuable in many ways, one of the most important of which will be that of affording suggestions to educational institutions and students on topics for investigation in metallurgy.

The metallurgical department of Case School of Applied Science under the efficient direction of Professor H. M. Boylston has already produced a number of very interesting investigations. These have been conducted not only at the school laboratory but also in the laboratories of various industries of Cleveland that have been placed at the disposal of the institution. An excellent exhibition of co-operation deserving of greater emulation.

Many other educational institutions have expressed a desire to co-operate with Colonel White and his committee and it is believed and expected that this phase of the Research Committees' work will continue to grow in volume and in importance.

TECHNICAL SOCIETIES TO WORK WITH THE BUREAU OF STANDARDS

THE spirit of co-operation which is being manifested in the formation of a committee representing numerous technical and scientific societies to work in harmony with the United States Bureau of Standards, is something we are pleased to see. Such an intimate relationship with the bureau can only result in a marked betterment for scientific research with a very much less duplication of effort on the part of all concerned. In the past a great deal of research work has been conducted by many different institutions with a result that much of the work was duplicated which means both a waste of energy and money. With this new relationship between the bureau and the many societies and associations we look forward to a very decided benefit to all and a marked saving in the total amount of money which will be expended in carrying out the researches.

It is patent that concerted effort makes for efficiency therefore with a close co-operation of all parties involved a long stride for the improvement of our scientific knowledge will be the reward.

FOOTPRINTS

THE study of biographies and accomplishments of distinguished men is one of the requirements of the University of Pittsburgh for students in the engineering divisions. This phase of the work was very forcibly presented by Chancellor Bowman when he spoke before the Pittsburgh Sectional Meeting of the Society.

One may readily understand the inspiration obtained from the study of the biographies of such distinguished men as Washington, Lincoln and Stanley. The vicissitudes and struggles they had to meet as well as their ability to accomplish successfully problems presented, could not but help impress the reader and form in his sub-conscious mind a resolve to emulate and endeavor to accomplish something worth while so that his life might also be a means of inspiration and guidance for future generations.

While the late Dr. Howe did not have to undergo the trials and tribulations of early youth as Lincoln did, nevertheless the perseverance and steadfastness with which Dr. Howe undertook and continued his researches in iron and steel demonstrated that his early education and training had been along lines designed to accomplish successful results.

The life of Dr. Howe and the results of his many researches and discoveries should be studied with careful thought, keeping in mind always that a research is not finished until it has been viewed from all angles and most exhaustively studied.

The metallurgical profession will view the life and accomplishments of Dr. Howe as a source of continued inspiration, and will gather from these a desire to contribute to the advancement of progress in iron and steel While the loss of Dr. Howe is great and appalling, one may nevertheless take comfort in the thought that his works will live after him and that:

"Lives of great men all remind us
We can make our lives sublime,
And, departing, leave behind us
Footprints on the sands of time."

THE QUESTION BOX

UNUSUAL interest is being shown in the Question Box Department of the TRANSACTIONS. We have had many favorable comments from our membership. We frequently hear the statement, "I am particularly interested to see the answers to the this or that question." It is gratifying to know that a growing interest is being stimulated through this feature of our publication, however we are not getting the support from the membership as a whole either in the receipt of questions or answers to questions. Undoubtedly a large number do not realize they can contribute to the enlargement of this department.

The Question Box is intended for your use and it is urged that you avail yourself of the opportunity of making it work for you. Probably there are some members who would like to contribute answers but who feel that they do not care to have their name appear as a contributor. In this respect a new policy has been adopted whereby the author's name will be withheld and retained in our files, in cases where he makes such a request. Your confidence and co-operation in making not only this feature but all other features of the TRANSACTIONS a success is the one way in which the Society will progress and attain the goal for which we are aiming.

A NEW PRODUCT

IF a new product is to be placed upon the market and the sale of it is to have sufficient success to repay the manufacturer, it is first necessary that the product should be thoroughly tried out in order to determine whether or not it is well suited for the purpose it is intended. Every year many new products are placed upon the market not only of mechanical devices but also of human beings.

Each year the technical schools are turning out many young men who during their junior and senior years have specialized in metallurgical subjects and when they have received their degrees are placed upon the market for consumption in the various steel manufacturing and fabricating plants There is no objection to the quality and quantity of work given to and performed by these embryonic metallurgists, the great difficulty being the unwillingness of these individuals to permit themselves to be thoroughly tested and tried out before demanding a compensation for their services entirely out of proportion to what they are able to deliver.

One university of repute graduating twenty-three individuals from the metallurgical department has so far succeeded in placing but five of the number. While many opportunities have been offered to these graduates to obtain minor positions in the laboratories of steel mills and government bureaus, they have nearly all declined because the remuneration did not seem to be in proper proportion to their own estimate of their value. There is a grat responsibility resting upon educational institutions to impress upon the members of their graduating class that before they may rise above the 'common herd' it is necessary for them to demonstrate their ability and that during this process they should consider salary as of minor importance and the opportunity to apply in a practical way the technical information they possess as the greatest in importance.

DETROIT CONVENTION

THE General Convention Committee of the Detroit Chapter of which Billy Woodside is chairman, held a very important meeting at the D. A. C. Club on June 16 when the chairmen of the various sub-committees gave reports of progress.

W. P. WOODSIDE

The Papers Committee of which Mr. C. N. Dawe is Chairman, advised that the Committee had been very successful in obtaining a large number of very high class papers and that it was sure a great amount of interest and discussion would be brought forth because of the originality and diversity of the subjects presented.

Mr. D. J. Crowley of the Hotels Committee stated that the hotels were beginning to receive very heavy reservations and that it was advisable that all members should make their reservations as soon as possible for Convention week. Some members have experienced difficulty in securing single rooms with bath because of the tendency on the part of the hotels desiring to have at least two in a room. In case any of the members should have difficulty in securing the accommodations they wish, Mr. Crowley suggested they should write him direct at 832 Dime Bank Building, Detroit, and he would see they were properly taken care of.

The Finance Committee under the direction of Mr. C. T. Bragg has plans arranged for the securing of sufficient money so that the entertainment features of the convention will be very ably taken care of.

The Entertainment Committee of which Mr. Frank G. Davis is chairman, has formulated a program that will keep the members enjoying themselves from the time they land until they leave the Motor City.

The Plant Visitation Committee has arranged a number of very interesting visits to some of the largest heat treating and forging plants in Detroit. Plant visitation in itself will be well worth a trip to the Michigan Metropolis because it will be possible for the members to visit plants during October 2nd to 7th that otherwise they would be unable to see.

The ladies are not to be neglected but it is assured that they will have as enjoyable a week as they have ever had at any previous convention and the conventions of the Society have been noted for the excellent manner in which the ladies have been taken care of. Larry Learmouth will have charge of this phase of the convention.

The Transportation, Information and Publicity Committees also presented encouraging reports and told of the plans they had worked out for securing the proper results by their committees at the appropriate time.

Mr. Jack Dailey, Chairman of the Local Exhibit Committee presented his report showing that all of the spaces originally shown on the floor plan had been sold and that it was necessary to open up additional booths so that all exhibitors who desired to show their products could be accommodated.

All indications point to the largest convention and exhibition the

Society has ever held and there is no doubt but that members should begin to make their plans now so as to be able to attend.

REPORT OF PITTSBURGH SECTIONAL MEETING

THE second of our sectional meetings which are held in various parts of the country was held in Pittsburgh May 25 to 27 at the Bureau of Mines. About 250 members of the Society from various chapters throughout the country were in attendance.

The first session scheduled for Thursday afternoon, May 25 was opened by N. B. Hoffman, metallurgist, of the Colonial Steel Company and chairman of the Pittsburgh Chapter who extended an address of welcome to the visiting members and guests on behalf of the Pittsburgh Chapter.

Following this address of welcome the meeting was turned over to Dr. C. M. Johnson, Chief of Research, Park Works of the Crucible Steel Company of America, Pittsburgh, who was chairman of the session. After a few fitting remarks, Professor F. F. McIntosh, metallurgical department of the Carnegie Institute of Technology was introduced and presented his very capable paper entitled "Fibre in Steel and Iron". Prof. McIntosh's paper compared the structure of wood and steel and noted that metallurgists seldom consider fibre of importance. Prof. McIntosh pointed out that fibre goes back to the ingot and is determined to a large extent in the furnace and the ingot mold, and that subsequent rolling and deformation does not increase or decrease its presence. He made the plea that the metallurgists be allowed more freedom in specifying the manner in which the steel he has to heat treat should be manufactured. Numerous micrographs accompanied the presentation of this paper and are included in Professor McIntosh's paper which is published in this issue of the TRANSACTIONS. A lengthy and interesting discussion followed this paper.

Following Prof. McIntosh, a paper entitled "Factors Influencing Mass Heat Treatment" was presented by W. B. Crowe, who is metallurgist of the armor plate department of the Carnegie Steel Company, Homestead Works, Munhall, Pa. Mr. Crowe's paper and discussion is also published in this issue of the TRANSACTIONS.

The last paper presented at the Thursday afternoon session was entitled "A Discussion of Impact Testing Methods and the Results Obtained", by John M. Lessells of the Westinghouse Electric & Mfg. Company. Mr. Lessells' paper was published in the May issue of the TRANSACTIONS. The discussion which followed his presentation is to be found in this issue of the TRANSACTIONS.

Thursday evening somewhat over 100 members and guests of the Society assembled at the University Club where an informal banquet was served. It was a regular heat-treaters banquet as evidenced by the following menu:

MENU

Austenitic Puree ala Mongole

Celery Ghosts Ferritic Olives

Filet of Grain Refined Sole
with Dephosphorized Sauce

Open Hearth Vermont Turkey
with Electric Furnace Cranberry Sauce
Bessemer Sweet Potatoes
(Southern Crucible Style)
Spheroidal June Peas
Dendritic Lettuce
with Desulphurized Roquefort dressing
Frozen Puddled Custard
Pearlite Cake Demi Tasse Quenching Oil
Havana Smoke Stacks

Prof. A. E. White of the University of Michigan and past-president of the Society presented G. H. Neilson, President of the Braeburn Steel Company, Braeburn, Pa., and past president of the Engineer's Society of Western Pennsylvania, who presided over the meeting as toast-master. A very entertaining evening was enjoyed by all. The speakers included Dr. John G. Bowman, Chancellor of the University of Pittsburgh, Prof. Frederick Crabtree of the Carnegie Institute of Technology and Dr. John A. Mathews, President of the Crucible Steel Company of America. Dr. Mathews delivered a very interesting address entitled "Metallurgical Miscellany". This banquet and meeting was declared by all who attended as a decided success.

Friday morning, the members in attendance assembled at the William Penn Hotel where they were assigned to automobiles furnished by the members of the Pittsburgh Chapter and were taken to the Edgar Thompson plant of the Carnegie Steel Company where they reviewed the rolling of steel shapes, the blowing of Bessemer steel, and the melting of open hearth steel. Following the inspection of this plant, the visitors were escorted through the plant of the Westinghouse Electric & Mfg. Company and at noon time were served with a very delicious luncheon in the cafeteria. After the luncheon a short trip was conducted through the coil winding and electric locomotive departments of this plant. At 2 o'clock the party proceeded by automobile to the Bureau of Mines Building where the final technical session was held.

Professor H. M. Boylston, Case School of Applied Science, Cleveland, presided over this session. A. M. Cox, President and Treasurer of the Pittsburgh Commercial Heat Treating Company presented his paper entitled "The Abrasive Qualities of Plain Carbon and Alloy Steels". This paper was well received and rather freely discussed. It was published in the May issue of the TRANSACTIONS.

Following Mr. Cox, John A. Succop of the Heppenstall Forge and Knife Company, Pittsburgh, presented his paper entitled "Importance of the Proper Heating and Cooling of Steel", which was also published in the May issue of the TRANSACTIONS. The discussion of Mr. Succop's paper is to be found in this issue.

A paper entitled "'Manufacture of Springs" by D. A. Smith of the Union Spring and Manufacturing Company, New Kensington, Pa. was read by title, as Mr. Smith was confined to his bed due to illness.

The last paper of the session was delivered by M. A. Grossmann metallurgist of the Electric Alloy Steel Company, Charleroix, Pa., and was entitled "The Change in Dimensions of High Speed Steels in Heat Treatment," published in the May issue of the TRANSACTIONS. This paper brought forth a large amount of interesting discussion and proved to be a subject in which many of the members were very much

interested. Mr. Grossmann handled the discussion in a very capable manner and his discussion likewise appears in this issue of the TRANSACTIONS.

Friday evening those in attendance were entertained by the Pittsburgh Chapter at a smoker in the Bureau of Mines Building. A very interesting and entertaining evening was enjoyed by all after which a buffet luncheon was served.

Saturday morning, the Board of Directors assembled for a business meeting.

SOCIETIES TO CO-OPERATE WITH BUREAU OF STANDARDS

IN order to keep in close contact with the iron and steel industry so that investigations conducted by the Bureau of Standards will be along the lines meeting the needs of the industry in general and pertaining to the fundamental properties of iron and steel, an advisory committee on ferrous metals has been appointed to work in close contact with the Bureau. This committee is made up of representatives of several scientific and technical societies interested in iron and steel. The societies represented by this committee are the American Society for Testing Materials; the American Institute of Mining and Metallurgical Engineers; the American Association of Steel Manufacturers, Society of Automotive Engineers and the American Society for Steel Treating.

On June 2, this Committee assembled for a conference at Washington, D. C. The following men were present representing their respective societies:: Bradley Stoughton, Consulting Engineer, New York, and Dr. John A. Mathews, President of the Crucible Steel Company of America representing the American Institute of Mining and Metallurgical Engineers; H. T. Morris, Bethlehem Steel Company, South Bethlehem, Pa. representing the American Society for Testing Materials; E. F. Kenney, Midvale Steel & Ordnance Company and Hugh P. Tiemann, Carnegie Steel Company representing the American Association of Steel Manufacturers; G. E. Norris, representing the Society of Automotive Engineers; Prof. A. E. White, Director of Engineering Research, University of Michigan and T. D. Lynch, Westinghouse Electric & Mfg. Company, East Pittsburgh, representing the American Society for Steel Treating.

A. A. Stevenson, member at large and J. H. Parker representing the American Society for Testing Materials were unable to be present.

There were present at the meeting from the Bureau of Standards: Dr. S. W. Stratton, Dr. G. K. Burgess, Dr. Hildebrand, H. J. French, Mr. Caine, Mr. Lundell, Dr. Rawdon, Dr. Jordan and Mr. Freeman.

Dr. Burgess had prepared a very comprehensive program to be reviewed by the committee. The discussion was opened by Dr. S. W. Stratton who gave an interesting talk on the purpose in bringing this committee together, stating that it was the desire of the Bureau to get first-hand information as to what problems, along metallurgical lines are potent and which should be investigated, and to get such help as the committee could give in placing the work of the Bureau on the best commercial basis possible. He referred to the non-ferrous committee which had been working for about a year and one-half and stated that

this work had been a very great help to the Bureau with the result that considerable had already been accomplished in connection with this work. As to the action of this committee it was pointed out that other societies in addition to those already represented might probably be added to the committee personnel. Such societies as the American Foundrymen's Association; American Railway Association; the American Electrochemical Society and the National Research Council were suggested. It was also suggested that the appointment on this committee of a few individuals might be especially desired on account of their associtaions, namely Dr. Albert Sauveur, of Harvard University, Dr. Wm. Campbell of Columbia University, and Frank Carney, consulting metallurgist of New York.

The question of time and frequency of meetings was discussed and it was thought advisable to have meetings about once every six months, one in the fall and the other in the spring in order to keep in touch with the work the Bureau is doing and also to keep the Bureau in touch with the work that others are doing throughout the country.

The question of numbering of steels was taken up and discussed at some length with reference made to the work which the Standards Committee of the American Society for Steel Treating is doing and the work that the Society of Automotive Engineers has already done in standardizing the numbering of steels. The Bureau expressed a desire to hear from different organizations as to what part they might probably play in such a standardization.

Mr. Norris brought out that the Society of Automotive Engineers felt that the work which they had already done is for the present at least, quite satisfactory to that organization and that if any change from their present scale were made, it should be very carefully considered before being established, but he did think that the Bureau could accomplish good work in establishing this numbering system, and making it a clearing house to which additional numbers might be added from time to time.

Dr. Hildebrand reviewed the methods which had been adopted by the Bureau in establishing and distributing standard chemical samples and asked for any suggestions that might add to the improvement of the method now in use.

Dr. Jordan gave a talk on the subject of gases in steel and how to determine them and the changes which take place in heat treatment due to the presence of these gases.

Mr. Freemann discussed rolling mill problems, the amount of reduction and its effect upon steel.

Mr. Fletcher gave a talk on the values of steels at high temperatures and stated that the engineers at the Bureau were in a position to make tests on steel while at high temperature and determine its physical properties under these conditions. Mr. Freeman discussed the tests which had been made upon railroad materials and he went into considerable detail on a lot of the tests that are now being run, covering thermal stresses in wheels, wheel composition, titanium treated rails, ingot practice, etc.

Dr. Jordan reviewed the subject of iron-carbon-manganese alloys bringing forth the work that is now being done by the Bureau.

The corrosion of chrome steels was discussed by Dr. Rawdon who reviewed the work which the Bureau has done relative to the corrosive

qualities of different steels and the importance of having steels that did not corrode, and their use in measuring apparatus and other places where corrosion causes trouble. He also discussed the subject of testing wrought iron and importance of more definite methods of testing this material stating that the old methods had become antiquated and that the results obtained did not reveal the real merits of wrought iron.

Mr. French discussed tests of high speed tool steels covering the important features and steps to be taken in obtaining standard bars on which to test high speed steel. There was a consensus of opinion of those present that in general it is necessary to test steels according to the type of work it is intended the tools are to perform giving as nearly as possible the working conditions.

It was stated that the Bureau has associates working with the Bureau and maintained by different manufacturing organizations for the purpose of working out their problems and with the provisions that the findings are at some later date published. The companies maintaining these associates obtain the benefit of first-hand information and are enabled to use these data before this knowledge could come into the hands of any competitors.

As this meeting was called primarily for the purpose of organizing and outlining the possible actions of the committee and the method of attack to be used, no definite action was taken. The thoughts conveyed by the various members of the Bureau of Standards were left as food for thought to be more minutely discussed at the next meeting.

Following the adjournment of this session the visiting committee was escorted through the laboratories of the Bureau.

SHOW YOUR COLORS

NOT so long ago a gentleman from Chicago had occasion to go abroad. While the liner was leaving New York harbor our friend was on deck scanning the sky line of the famous city, his eye happened to catch a glimpse of an emblem that a fellow passenger was wearing on his waist coat. It looked familiar and upon closer examination he found it to be similar to the one he was wearing. It was the ensignia of the American Society for Steel Treating.

The fact that each was wearing the emblem of the Society immediately placed these two men on the same plane which resulted in a very interesting and companionable voyage. When they arrived in England they inspected several steel mills and spent many profitable hours together. This chance meeting through the medium of a society emblem is not at all unique. It happens frequently and incidentally usually results in warm friendships.

The wearing of the Society's insignia places a man in a class which identifies him as a progressive student of science and technological advancement. Our society is an internationally recognized institution for the advancement of steel metallurgy and membership in the society is something of which to be proud.

The insignia of the society is familiar to most of our members, being in the form of a small circular safety clasp pin having an especially attractive arrangement of the initials A. S. S. T.

FIBRE IN IRON AND STEEL

By F. F. McIntosh

THE earliest workers with iron and steel recognized the fibrous character of these metals. It was an easily recognized characteristic and it had a marked effect upon the performance of the metals. When the scientist turned his microscope on these metals he made many interesting and valuable discoveries. He found that they were made up of grains or constituents which he named ferrite, pearlite, cementite, austenite, etc. It would be hard to overestimate the value of his work, but he worked so very close to his metal, that in many instances, he lost sight of some of its very important characteristics. You will find that some of his books say that wrought iron is not fibrous. He may tell you that it is made up of grains of ferrite and stringers of slag, and that the grains of ferrite are granular or crystalline and therefore wrought iron is not fibrous. He recognizes the true structural condition of the metal but he is very apt to overlook the influence of its condition upon its ultimate performance. He frequently fails to recognize the fibrous character of steels or its full influence upon the performance of the metal. In many instances he is not given control of the manufacturing conditions which govern the formation of the fiber or grain of his metal, and he is required in the working and treating of the steel, to secure results with material in which his only specification has been chemical composition.

If the chemist were given pieces of wood, one of hemlock and one of hickory, he would probably show no more difference between the chemical composition of the two kinds of wood than might be found between two heats of steel manufactured within the limits of an ordinary steel specification. If we were to make one sledge handle of hickory and one of hemlock the difference in performance of the two woods would be easily observed. It would be the difference between success and failure and it would be the result of differences in fibre or grain of the two woods. Differences of the same general character and magnitude exist in irons and in steels.

The metallurgist should pay more attention to the fiber or grain of his metals than he usually does, and he should take the stand "that taxation without representation is tyranny," that is, if he is to be held responsible for the working and heat treatment of the metals, he must be given control over the conditions which govern fiber. He can often work himself into the proper position, in this respect, and without revolutionary methods, if he makes the examination for fiber a routine inspection just as he now requires a chemical analysis or a tensile test.

The object of this paper is to direct attention to the importance of fiber in the performance of iron or steel under test or in service, and to indicate the factors which govern its formation and character. The paper has been suggested by the many instances which have been observed where chemical composition and treatment of metal have been according to specification, but the metal has failed to stand up in service. An examination for fiber often shows the cause of failure. It has been observed that in many instances the metallurgist neglects this examination, and, in his great interest in the microstructure, overlooks the importance of fibre or grain as shown by methods of macro-etching. The importance of this subject cannot be over-

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A paper presented at the Pittsburgh Sectional meeting, May 25-27. The author Prof. F. F. McIntosh, is professor of metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

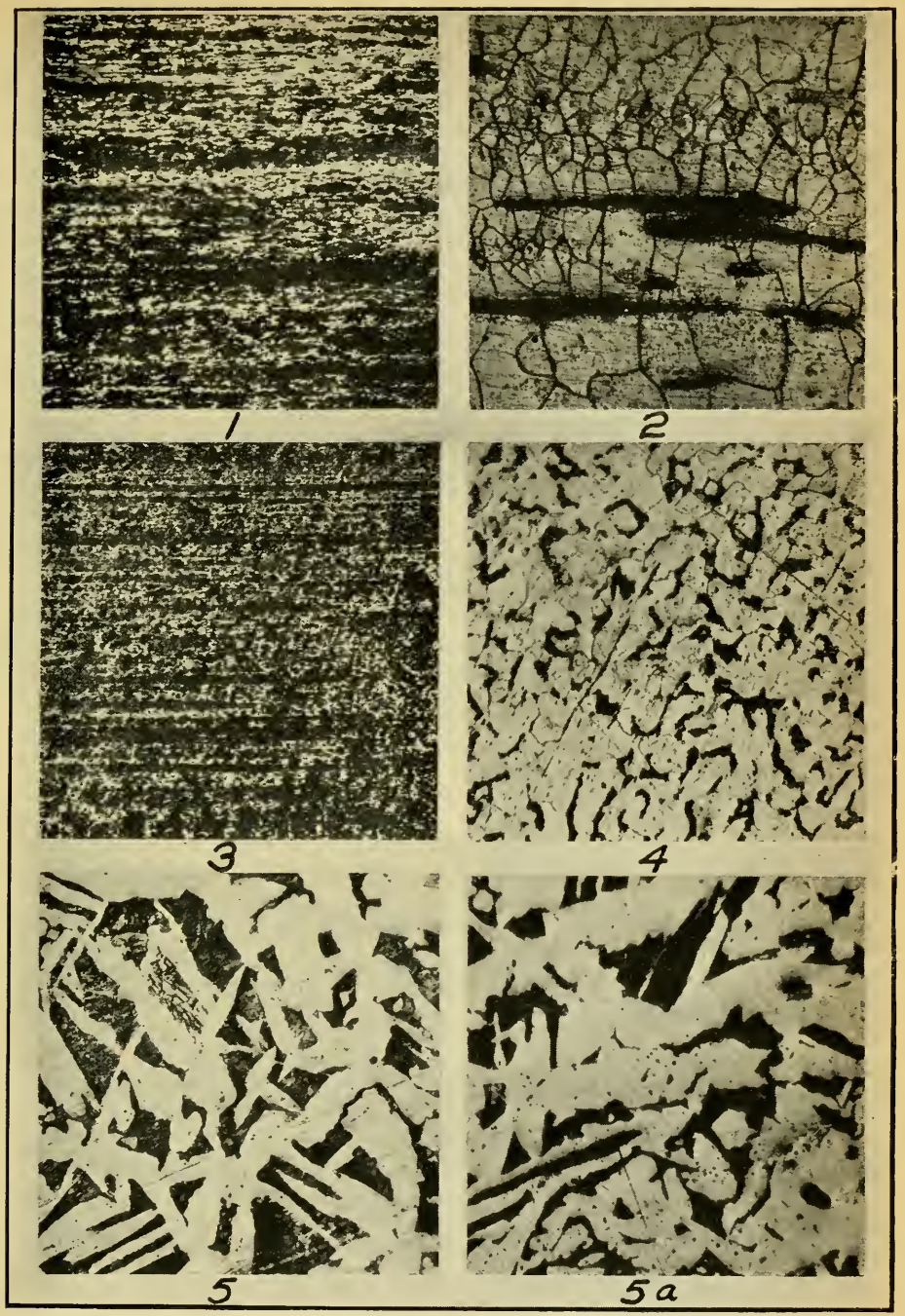


Fig. 1—Macrostructure of a longitudinal section of wrought iron showing the decidedly fibrous condition of the metal, 3.6X. Fig. 2—Photomicrograph of a longitudinal section of wrought iron showing stringers of slag and ferrite grains, 150X. Fig. 3—Macrostructure of a low carbon steel showing the fibrous nature of the material, 3.6X. Fig. 4—Photomicrograph of a low carbon steel showing only faint traces of fibre as disclosed by small thread-like nonmetallic inclusions. Fig. 5—Photomicrographs of a transverse section of a steel plate, rolled in two directions, showing the absence of fibre. Fig. 5a is a longitudinal section of the same plate. 150X.

emphasized. A recognition of its importance and an intelligent control of it under manufacturing conditions would often mean a big improvement in quality of product and a saving through improved performance of metal and fewer failures in service. Intelligent control can only be obtained by a thorough and correct understanding of the character of fiber and all of the factors which govern its formation. The practical man and experienced manufacturer who recognizes fiber and sees, in a measure, its importance, should demand the co-operation of the metallurgist who understands its causes and character. There has been too little of this kind of co-operation. The metallurgist has held too close to the laboratory and his microstructure. The manufacturer has been too much absorbed in the problems of production.

In all lines of manufacturing activities we are facing a most serious situation in the form of German competition. A study of the German methods will show many reasons for his success. The outstanding reason, the one which will be the cause of much of our worry, goes back to the fact that he has applied science to his industries. The fiber in steel may seem like a small detail, but, if a German rail performs better in service than an American rail, the difference in fiber might readily be the cause, and the result be the loss of South American rail contracts. It is hoped that this paper will succeed in indicating the importance of the subject. In a short paper of this kind it is impossible to make a thorough and comprehensive exposition of the subject, however, we shall, by means of photographs and photomicrographs illustrate the subject with a few simple examples. As a first example, let us consider a piece of wrought iron, a material which we have been told is not fibrous. A comparison of longitudinal and transverse tensile tests shows a marked variation in the physical properties of the metal.

	Ultimate Strength Pounds per Square Inch	Yield Point Pounds per Square Inch	Elongation per cent in 2 inches	Reduction Area in per cent
Longitudinal	47,400	29,600	16.0	21.9
"	47,600	29,000	25.0	21.9
Transverse	32,800	22,600	2.5	5.2
"	28,400	19,800	2.0	2.4

The wrought iron has much greater strength and ductility in the longitudinal direction than it has in the transverse or across the fiber direction. When the material is etched for fiber or macrostructure it shows a decidedly fibrous appearance with the fibers running in the direction of maximum strength and ductility as shown in Fig. 1.

When the microstructure is examined the usual structure of stringers of slag and grains of ferrite are observed as shown in Fig. 2. It is desired to direct attention particularly to the fact that ferrite grains are arranged in longitudinal bands. These bands are easily distinguished by their difference in grain size, a difference which is probably the result of variations in composition. The metallic portion of the wrought iron is made up of longitudinal stringers of ferrite. The ferrite grains might be considered as similar to the cell structure of wood and the banded arrangement as representing the grain of wood or fibers of a rope.

This examination shows that wrought iron is a heterogeneous material composed of longitudinal stringers of slag and longitudinal bands of metal, and that it has much greater strength and ductility in the direction of the bands or fiber (longitudinal) than it has when tested across the fibre (transverse). Practical experience has shown many interesting results with this

material, and, in spite of the fact that many writers have said that it is not fibrous, the test of service has enabled it to hold the field in service such as stay bolts, at a cost of at least 30 per cent more than its rival. There are evidently some factors in connection with the fiber of this material which are not understood.

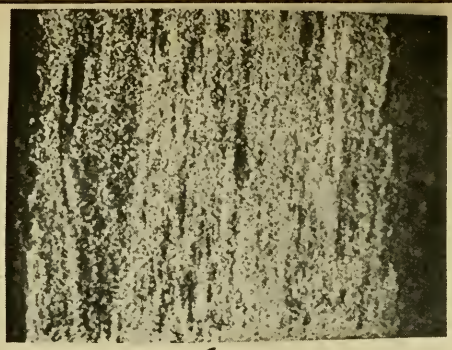
Whether or not wrought iron is fibrous depends largely upon the definition of the word fibrous. It is certainly made up of longitudinal stringers or films of slag and longitudinal bands or fibers of ferrite grains. Like a piece of wood or rope it has longitudinal strength, and transverse weakness resulting in flexibility. A long discussion might be developed on the use of the word fiber, however a wrangle of this kind would add little to our technical knowledge. It has been suggested that the term fiber might be used wherever the material has been extensively elongated. The author believes, however, that it would be best to abandon the word fiber entirely where metals are concerned and use the word grain. The word grain would apply equally well to either cast or forged material. The objection to the use of the word grain is that it is frequently used to refer to microstructure of the metal and every effort should be made to avoid confusing the microstructure with the macrostructure. The important thing, after all, is not so much the word used, as it is the general recognition of the heterogeneous character of the metals and the importance of this characteristic. The characteristics of fiber or grain are not confined to wrought iron. They are present in all steels and the following examples have been selected to illustrate this point. Longitudinal and transverse tensile tests were made on a sample of low carbon steel which had been rolled into a long flat section. The results of these tests are as follows:

	Ultimate Strength Pounds per Square Inch	Yield Point Pounds per Square Inch	Elongation per cent in 2 inches	Reduction of Area in per cent
Longitudinal	55,600	36,200	54.0	51.4
"	43,200	36,400	54.0	56.3
Transverse	54,700	35,200	....	33.6
"	54,900	35,000	....	42.9

There is little difference between the transverse and longitudinal strength of this material; the transverse test being slightly lower in yield point. The effect of fiber, however, shows up very clearly in the ductility of the material. The transverse samples broke outside of punch marks, but reduction of area tells the story. Fatigue or impact tests would also show a marked difference resulting from fiber. The macrostructure, Fig. 3, shows the fibrous nature of the material, the microstructure Fig. 4 shows only faint traces of fiber as disclosed by occasional small thread-like nonmetallic inclusions.

Transverse and longitudinal tensile tests from a steel plate rolled in a plate mill, rolled in two directions, from ingots designed for plate mill work indicate that fiber is absent in this material.

	Ultimate Strength Pounds per Square Inch	Yield Point Pounds per Square Inch	Elongation per cent in 2 inches	Reduction of Area in per cent
Longitudinal	62,750	36,000	34.0	50.5
"	63,450	35,500	32.5	46.5
Transverse	62,750	37,000	30.0	46.5
"	62,200	36,000	30.0	50.5



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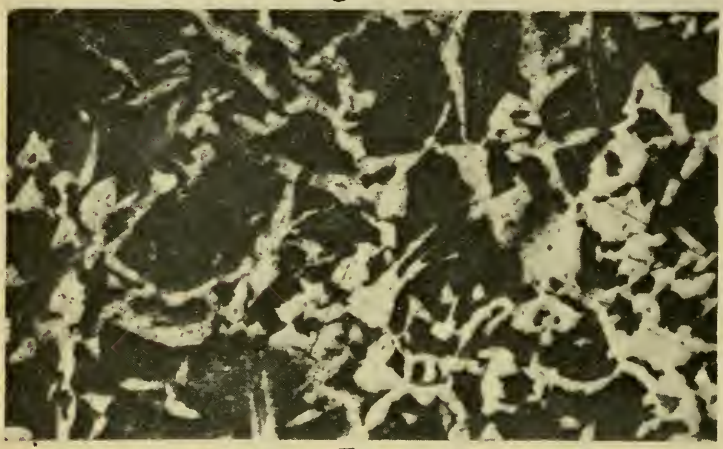

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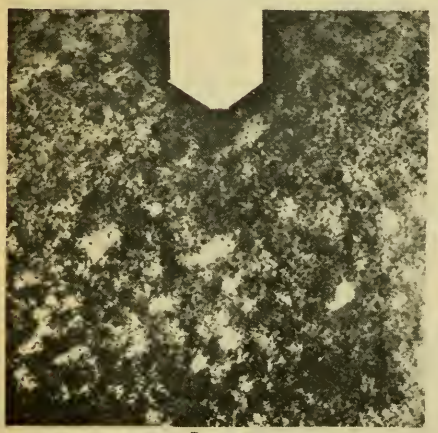

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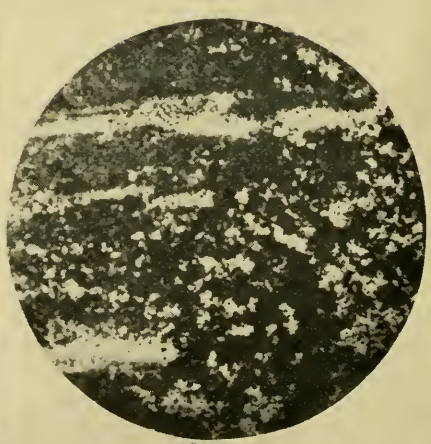

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Fig. 6—Macrostructure of a longitudinal section of the steel plate, rolled in two directions, showing the elements of fibre which were well developed but not evident in photomicrographs in Figs. 5 and 5a. The fibres are present in sheets like the leaves of a book. Magnified 3.6X. Fig. 7—Photomicrograph of a transverse section of a high grade acid steel forging showing no banding or indication of fibre. 150X. Fig. 8 is the macrostructure specimen shown in Fig. 7. The presence of fibre is clearly shown. Fig. 8a is a macroetching of the transverse section of the same specimen. 3.6X.

Photomicrographs of this material, Fig. 5 and Fig 5a, taken from transverse and longitudinal specimens do not indicate the presence of fiber. Methods of macro-etching, however, reveal the elements of fiber which were well developed, as shown in Fig. 6. The fiber in this case is in sheets like the leaves of a book. The physical properties of the plate taken with reference to its length or breadth, that is, parallel to the sheets of fiber, do not show variations. If a tensile test were taken through the thickness of the plate it would be a transverse test and would give lower physical results.

Transverse and longitudinal tensile tests taken from a high grade acid steel forging containing about 0.40 per cent carbon and 0.58 per cent manganese, shows the effect of fiber.

	Ultimate Pounds per Square Inch	Yield Point Pounds per Square Inch	Elongation per cent in 2 inches	Reduction of Area in per cent
Longitudinal	91,750	48,000	24.0	36.0
Transverse	89,250	48,250	17.0	25.1

The microstructure of this material, Fig. 7, shows no banding or indication of fiber, but the macrostructure, Fig. 8, shows the fiber and explains the reason for the low elongation and reduction of area shown on the transverse tensile test. It is not difficult to trace the fiber back through the different states of manufacture. Its study affords valuable information as to the flow and working of the metal and the casting conditions. It shows that fiber or grain originates at the time the metal solidifies and that its character is determined by three main factors:

1. The condition of the molten metal
2. The conditions of solidification
3. The flow of the metal during forging, pressing or rolling

For example, take a cross section of a 4-inch x 4-inch billet. Under examination for fiber or grain, it shows the outer ring metal resulting from the dendrite growth on the face of the mold and the corner lines and distortion due to rolling. The central zone of freezing is quite distinct. It might be likened to the trunk of a square tree with outer shell or sap wood and inner core or pith wood. This condition is shown in Fig. 9. A second example, illustrating the persistance of grain and the effect of different macro-etching agents, consists of a section of splice bar about 4 inches long. One end of this section was etched with sulphuric acid, Fig. 10, the other end of the same piece was etched with Humphrey's reagent, Fig. 11.

The grain of the metal shows the distortion which the original ingot had received. A longitudinal section would show a marked fibrous appearance. The Humphrey's reagent has left a high phosphorus area standing in relief in the center of the section, while the sulphuric acid etch has removed this same area and left a deep cavity in the center of the section.

Fig. 12 is a macrograph of the grain of a 0.50 per cent carbon basic steel ingot reduced to one half full size. Fig. 13 shows the same material magnified 3.6 times. The grain which is so obvious in all of these macrographs persists through all normal working and treating of the steels. It represents an important characteristic of steels, a characteristic which is not considered as carefully as it should be by our manufacturers and metallurgists.

These examples all illustrate the well known fact that iron and steel

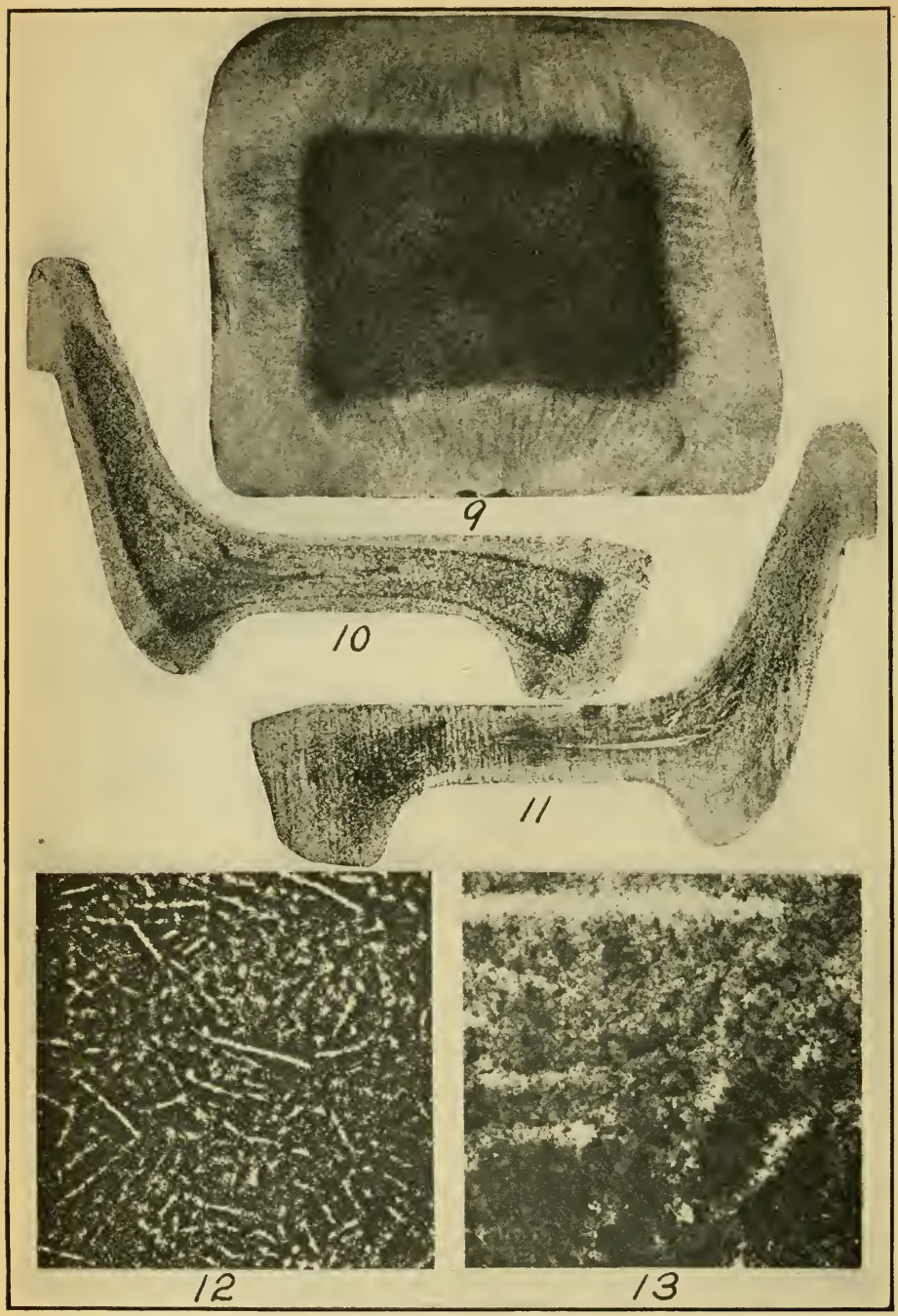

Fig. 9—Macrostructure of a 4 x 4 billet showing outer ring of metal resulting from the dentritic growth on the face of the mold and the corner lines and distortion due to rolling. The central zone of freezing is not quite distinct. 3.6X. Fig. 10—A macrograph of a section of a splice about 4 inches long etched with sulphuric acid. 0.7X. Fig. 11—Macrograph of the opposite end of splice bar etched with Humphrey's reagent leaving a high phosphorus area standing in relief in the center of the section. The sulphuric etch has removed this area and left a cavity. 0.7X. Fig. 12—Macrograph of 0.50 carbon basic steel ingot. 0.5X. Fig. 13—Macrograph of same specimen magnified 3.6X.

possesses structural characteristics and physical properties which are not uniform in all directions; characteristics which are the result of the fiber or grain of the material. A critical study by means of impact tests, fatigue tests, transverse tensile tests, and macro-etching of any class of iron and steel would show marked variations in properties of the material resulting from variations in methods of manufacture. The chemical and micrographic conditions might not vary, but the fiber of the material, the result of melting, casting, and working conditions would vary greatly. It is desired to emphasize the fact that fiber has a marked influence on the performance of metals and that chemical, micrographic, or longitudinal tensile tests do not indicate the character of the grain or fiber of the material. The fiber or grain of steel is the result of three main factors or classes of conditions as previously stated. It is desired to make a brief review of these three factors or causes which give to the steel a heterogeneity which persists through all treatments and which greatly influences its performance in service, which causes differences in the steels equal in magnitude and character to the differences which exist between a piece of hemlock and a piece of hickory.

The condition of the molten metal has great influence on the fiber of the finished steel. The temperature of the metal influences the rate of freezing and size of dendrites. The degree of oxidation has much to do with the amount of nonmetallic inclusions which collect between the branches of the dendrites. A steel which has been deoxidized in the ladle is like muddy water; all through the molten mass the reactions between deoxidizer and oxygen are going on giving nonmetallic mud which is trapped by the freezing metal and gives grain just as slag does in wrought iron. Gas in solution or trapped in the metal probably has some influence. The conditions of solidification regulate the size and character of grain through the phenomena of selective freezing. This phenomena gives the well known segregation at the top of the ingot, and it gives a similar segregation throughout the entire mass of the metal. Each crystal or dendrite as it forms follows the laws of selective freezing and results in a secondary or minor segregation or chemical heterogeneity throughout the mass of steel. A heterogeneity which persists through all heat and mechanical treatment. A heterogeneity, which, coupled with the nonmetallic inclusions, give the fiber or grain to steel. Micrograph Fig. 12 shows the character of this segregation. The phenomena of selective freezing is not difficult to understand, but attention should be directed to the fact that there is a secondary or reverse segregation which takes place in steel after it has solidified. This secondary segregation results in ferrite lines appearing in the finished steel at the places, where, at time of solidification the carbon was highest. This reverse segregation is sometimes overlooked in reading back from the macrostructure to the cause of fiber or of banding in steel.

The flow of metal from working, merely distorts the fiber or grain which formed when the metal solidified. There is nothing mysterious about this phenomena, but it is highly important in designing the different stages in the forming of metal articles. Sharp angles are always avoided in finished shapes and fillets are used freely but we are apt to overlook the fact that quick changes or distortions in fiber are just as serious. An additional operation in forging a crank shaft may ease off the fiber around a quick change in direction and mean the difference between a good shaft and a bad shaft. The macrostructure should be studied for every stage in the forging of a part before the final method of forging is adopted. Often great improvements can be made by slight changes in die design.

Discussion of Prof. McIntosh's Paper

MR. E. J. JANITZKY (Chicago): I would like to call attention to an article by Dr. E. Kothny of Traisen, Austria, which appeared on page 677, Stahl und Eisen, May 20, 1920, which deals with a specification for airplane crankshafts that required beside the usual statical test, a fracture test which had to reveal a fibrous texture. The test specimens had to show the following physical properties for acceptance:

	Elastic Limit Kilograms	Tensile Strength per Square Millimeter	Elongation	Reduction of Area	Notch Impact Meter Kilograms
Longitudinal	95/110	105/120	7%	45%	8.0
Transverse	95/110	105/120	4%	15%	2.5

The following chemistry was found to give these requirements:

Carbon	Manganese	Silicon	Nickel	Chromium
0.20%	0.40—0.60%	0.2—0.3%	4.0—4.5%	1.0—1.5%

The tests were taken in the following manner: Two test specimens were to be cut from each shaft, roughly forged, machined and used for the tensile and nick tests. The remainder of these pieces were to be nicked vertical to the longitudinal axis and broken under the press in order to expose the fracture in a larger area. The nicked tests of the longitudinal pieces and the fractures of the other samples had to show a fibrous structure and a good tendency to flow.

In the manufacture of this steel in consecutive heats it was revealed that although the tensile tests were satisfactory the fibrous fracture could not be obtained. An investigation was therefore conducted.

The results of this investigation were startling. Through a serious of careful tests, the working conditions were observed and determined for the manufacture of chrome nickel steel in the electric arc furnace for airplane shafts.

The following conclusions were derived:

1. Only high grade material should be charged.

2. Even when using the purest base, two oxidizing slags previous to the refining slag must be worked in order to obtain the fibrous structure in the heat treated state.

3. The method of adding the deoxidizers and the ferrochrome has no influence on the fracture.

4. The temperature of the ingot mold and the method of pouring (top and bottom) have no influence either.

5. A long duration of solidification which can be due to hot pouring or the use of sand molds produces a steel which shows a strong transverse fiber in the worked state.

6. A manganese content exceeding 0.80 per cent makes the structure granular in the heat treated state.

It is also noteworthy that metallographic examination did not differentiate between a granular or fibrous fracture.

Point 2 of the above conclusions invites the investigation of metallurgists.

Point 5 seems to give the answer to Professor McIntosh's paper.

PROF. McINTOSH: I am not sure I caught all the points you present, but I think I have some of them and I am glad you mentioned them because they bring out the thing that I spoke about when I started; that is,

that we are lacking in a specific nomenclature to cover what we are talking about.

We speak of a woody fracture, and when we speak of that we refer to a woody fracture in the test piece, I take it. That is not what I am trying to point out. That is a well defined phenomena, and my analogy of hickory and hemlock probably coupled up with your woody fracture has caused a certain amount of confusion. I am not speaking of fractures at all in this work. I am speaking of fiber in steel, which depends on the conditions of melting and casting the steel. You might get a fibrous fracture or you might not, but I still maintain that all steel you get will have these characteristics which I have called fiber for lack of a better name, which I have suggested might be called grain, and I foresaw the conflict due to the difference between the microscopic structure and the macroscopic structure.

You spoke of crank shafts. I saw a very interesting application of this study, of the kind of fiber I am trying to talk about, in the manufacture of a crank shaft by a well known automobile maker. They had trouble with a breaking off where the shaft joined the disk at the end of the crank. A study of the kind of fiber that I am talking about showed that the grain of the steel, or the fiber, had been very much disturbed when it made that sharp change from the straight round shaft to the circular disk; just as if you abuse a piece of wood, and wreck the fibers, you cause a weakness. They changed the method of making crank shafts, put in an additional step to ease the flow of the metal from shaft to disk and those troubles disappeared.

I have seen the same thing in the manufacture of cartridge cases, which is a very severe process as far as the flow of metal is concerned. By studying the grain or fiber of that material and changing the punches and dies so that the material flowed gradually and wasn't abused in any of the operations by making a sudden jump in the grain of the metal which could not be remedied by heat treatment, it was possible to make a superior case.

I have seen the same thing in shell forgings. You remember the button, that, under certain conditions, used to fall out. They were afraid of prematures as the result of it. That button was merely due to abusing the kind of fiber that I am talking about. That is, with improperly designed punches and dies, from the very start, there was a bit of dead metal ahead of the punch, and off to both sides of that was metal that you flowed excessively, so that you had a cone of rupture between the material that was flowing and the dead metal in front of the punch. By developing proper shaped punches that source of danger was eliminated.

MR. N. B. HOFFMAN (Pittsburgh): Is there any formula you can use in a percentage reduction, to completely remove the dendritic structure in a carbon steel?

PROF. McINTOSH: You can't remove it at all. Your formula of reduction merely means how much you are going to draw it out. The work of Charpy and others has shown, for example, that excessive reduction reduces the transverse test values of steel. That is because it introduces more of these lines of weakness. I think one of the reasons that a crucible steel performs better than a similar grade of steel in larger ingots is due to the fact that with a smaller ingot you get small dendritic growth, and fine fiber; but I am still convinced that you will get fiber or something corresponding to it. It may not be clearly visible in all steel. But I think in order to really get rid of fiber you will have to go back and change the laws of nature which govern selective freezing.

MR. HOFFMAN: Then a larger ingot would take more reduction than a smaller ingot?

PROF. McINTOSH: There are so many factors in a thing like that. that I would hate to commit myself. I wouldn't attempt to make a genera statement on a thing of that kind.

MR. J. M. LESSELLS (Pittsburgh). I would like to ask if you are putting forth the theory of trying to get rid of the fiber? The more fiber you have the higher reducing properties you are going to have.

PROF. McINTOSH: If you take out the fiber from a piece of hickory or reduce the amount of fiber, you might get a wood like boxwood, but it wouldn't do the work that hickory does. No, I am not making an attempt to say that the elimination of fiber would give you better material, but I am attempting to say that fiber is of prime importance in the performance of the material. I don't even say it is desirable. I wasn't attempting to say we should abandon chemical analysis or abandon microscopic examination. But I am trying to say that macroscopic examination is of prime importance and is a subject we have neglected, and that when a heat treater is compelled to get results with steel in which his only specification is chemical analysis, it is a case of taxation without representation.

MR. HOFFMAN (Pittsburgh): I believe you are pretty well on the way to beating nature to it when you spheroidize a square ingot. You eliminate your fiber structure to a great extent. You almost eliminated your fibrous material by spheroidizing.

PROF. McINTOSH: I don't think so, although in that particular zone the fiber would not be as marked as in the central zone. But that outer zone, just as in your ferrite here, would probably have differences in phosphorus content which would not disappear if spheroidized. I am inclined to think that the condition of gas in the steel has something to do with it. Any steel will have from 5 to 15 times its own volume of gas in it. That is about all we do know, but the steel that we have here is a basic steel, very low in phosphorus, and yet I think you will find that both zones in this steel contain fibre. In this very crude piece of etching you can see elements of fiber out in that outer zone. Of course when you make that into a rivet or telegraph wire or any structure, you have two combinations of fiber that show up.

MR. A. M. COX (Pittsburgh): When the company I was recently connected with first started the manufacture of motor pinions for street railways, they used bar stock. Upon deep etching for macrostructure practically each strain line could be traced from one end to the other parallel to the bar length.

The next step in the procedure was to go to upset forgings on account of the teeth breaking out easily when using bar stock. That helped some because the fiber or strain lines seemed to mesh in between, past each other and upset at the top and bottom due to the upsetting process of manufacture. The upsetting was used. So that, if a tooth should happen to break out, it would cause a breaking of fiber lines which would give you a stronger resisting tooth than possible with the forged steel bar.

About a year ago we tried first the upsetting and subsequent drop forging. We got the upset pinion results combined with the drop forging, which caused a flow of the fiber lines so that in order for a tooth to break out it had to cut more fiber lines or overcome greater resistance. The breakage has been practically eliminated by using the upset and drop-forged pinion. That is along the line of making use of the fiber lines in steel.

MR. E. E. THUM (New York): I would like to ask Professor McIntosh if he has been able to fix in his own mind the border line up to which nonmetallic inclusions are desirable as causes of fiber, and the other step beyond the danger line where they are undesirable as causes of woody fractures. I assume from your remarks that perfectly homogeneous metal is not desirable.

PROF. McINTOSH: I didn't mean to convey that idea if I gave it. I have not exactly made an effort to formulate what you have in mind. I have always been under the impression that in steel, nonmetallic inclusions represented something abnormal or undesirable. It is something like the imperfections of a human being—the fewer we have the better off we are, but none of us are ever perfect.

With fiber in steel, I think that nonmetallic inclusions should be only minor factors. Does that cover what you have in mind? I didn't intend to convey that it was my idea that fiber in steel is the result of nonmetallic conclusions. It may have something to do with it, but I didn't intend to convey the impression that you seem to have.

MR. THUM: Fiber is due to the nonuniform distribution of carbon rather than the presence of insoluble oxides such as result from deoxidizing operations in the steel furnace or ladle?

PROF. McINTOSH: Yes, as far as I know.

So many people confuse segregation as detected by the chemist with the segregation which gives fibre. If we had some good way of differentiating between microsegregation and macrosegregation such as we have in the structure, it would be good. That is my idea, and it is fairly well founded, that fiber is the result of this segregation which could not be detected by chemical analysis; it occurs all through the mass as the result of selective freezing, rather than the segregation which we detect by chemical analysis.

MR. ARTHUR GREEN (Philadelphia): Professor McIntosh, do you believe that, giving ourselves over to the belief that fiber is in steel in this shape the fiber becomes more developed in the working of that steel? Does it become more accentuated?

PROF. McINTOSH: It is only by working that you distort it. For example, here you might work down to a ½ inch round, and the fiber on cross section of the piece would not be very noticeable. It would merely represent little differences like that. But that extreme reduction in elongation would mean that longitudinally you would have drawn these chemical irregularities out and made them into very long fiber.

MR. GREEN: Suppose you have done that and put the piece of steel to work, is it natural for the lines to be further accentuated? The reason I ask that is that I have been noticing on one of the piston arms that we have in the mill, that there has developed a beautiful fiber structure. It is a connecting arm between the cog and the piston itself and represents roughly about 8 inches of material one way and 3 inches the other. The fibrous condition seems to grow, although I have made no measurements. I am wondering whether this fibrous condition is one that does accentuate itself.

PROF. McINTOSH: That is an interesting case. It is one that I wouldn't attempt to answer. I am doing, as I said, a lot of work on fatigue and we noticed that steels which were banded with well defined longitudinal bands of ferrite, gave a rather poor life. Of course what probably happens is that those bands represent material much weaker than the steel as a whole. Cold work sets up and goes on, you start a fatigue failure in one of the bands, and it progresses across the piece.

It probably is a banded steel and has ghost lines, and perhaps there is a little cold work leading up to failure by fatigue, and a tendency to corrode resulting from the cold work makes the lines visible.

MR. H. C. KNERR (Philadelphia): I would like to ask whether you consider that incompletely killed or gassy steel has anything to do with this question of "fiber."

PROF. McINTOSH: I was afraid somebody would get into that field and ask about the difference between effervescent steel and killed steel. I don't really know what it has to do with it. I would like very much to, though.

MR. W. B. CROWE (Pittsburgh): I would like to take the liberty of adding some of my experience with fiber to what Prof. McIntosh has already given.

I wondered, the first three or four years of my experience, just what fiber was, and was unable to arrive at any definite conclusions. The term fiber appeared to describe two widely differing properties in steel, one representing flow lines of hot worked steel as revealed by the macro-etch, the other a characterization applied to the fracture of very tough steel. I will take up the latter application of the term to begin with.

A very tough steel permits a pronounced grain distortion at the points of rupture, and the more pronounced this tendency, the greater will become the shock resisting properties, assuming the tensile and elastic strength to be a constant.

I have taken specimens from the so-called fibrous steels having had different treatments. The tensile and elastic properties were practically the same, and yet in many cases the fractures showing fine crystalline structure had a much higher percentage elongation and reduction than many of the specimens which showed a fibrous fracture. And yet experience has shown that the latter stood a much better dynamic test especially under high velocity of impact. The property therefore which a fibrous fracture appears to indicate is toughness rather than ductility. And this property is the result of the combination of correct treatment applied to the correct type of steel.

That mass increases the difficulty of obtaining fiber I will give an example: Two types of steel 3 inches thick were treated to produce a fibrous fracture. The specimens were increased in thickness to more than a foot. One type continued to show as good a fibrous fracture as previously described with 3 inch section. The other type persistently refused to develop a fibrous fracture.

These large fractures produced by a 12000 ton press showed much different characteristics. The one which was fibrous appeared to tear rather than break, and the operation was done so quietly that one would not know it had been completed if he were not watching closely; but in the other case there is a decided flexure, a sudden crash which may be heard nearly a thousand feet away, and a jar which one might think had wrecked the press. In both cases the speed of depression of the ram was the same.

So it seems to me that the fiber as revealed by fracture is an entirely different property from the fibrous internal structure of the metal, a property which is contrasted by composition combined with a definite treatment.

Regarding fiber as revealed by the macro-etch, I have found that steel which had not yet been rolled or forged did not develop a fibrous etch, that this type of fiber was an arrangement of sonims into definite flow lines, having the appearance of fiber, these becoming a fixture immovable by heat treatment. It is a question whether such a condition is desirable.

FACTORS INFLUENCING MASS HEAT TREATMENT

By W. B. Crowe

OF THE numerous factors, influencing mass heat treatment, the majority of them occur before the actual operation of heat treatment itself. Mechanical design is an important factor of influence and in a great measure controls the character of the heat treatment to be employed. It may render the process of treating extremely difficult, if not unsafe, and may even make satisfactory heat treatment impossible. There are many cases on record where failures which were at first attributed to inferior heat treatment were traced directly to faulty design, Since the advent of high test alloy steels into more general use, there has been a tendency on the part of designers to over reduce the mass of metal in a given component with the result that failure occurs in service. It is quite true that one of the prime objections in using the higher priced steels is the reduction of weight, yet there are cases where due to the nature of the stresses involved, such as torsional and bending stresses, a considerable reduction of mass cannot be made without introducing serious mechanical faults. Where such is the case and section is the controlling factor with reference to amplitude of flexure or torsion, the cheaper plain carbon steels with their usual physical properties may be used satisfactorily. There are cases, of course, where the most highly developed properties attainable are required, which naturally introduces the factor of composition as it influences the physical properties of large masses undergoing heat treatment.

Irrespective of the quality of the steel, its fabrication or subsequent heat treatment, unless the chemical composition very closely approaches the specifications established, the ultimate results will be more or less undesirable. All other fields of investigation in steel are small in comparison with the field of exploration in composition. The cost of evolving a new composition involves a very considerable amount of time and money. An entire melt is required for each new compositional experiment, each of which may take a thousand fabrication or heat treating experiments with the compositional problem still unsolved. As mass dimensions are increased the effect of composition becomes more pronounced. Specimens of laboratory dimensions may be selected from various types of steel ranging from the simplest to the very complex, which, when water quenched may show very similar physical properties. If the mass of these representative steels is very considerably increased, the physical properties will be found to have diverged greatly. For example, experiments made on 0.55 per cent plain carbon steel, 0.45 per cent carbon, chrome vanadium steel, a 0.45 per cent carbon, nickle chrome steel, a 0.40 per cent carbon, chrome molybdenum steel and a 0.47 per cent carbon, nickel chrome molybdenum steel. Specimens one inch in diameter were water quenched from experimentally predetermined temperatures. All specimens showed a sclerosocope hardness of 90 to 95 and with a Brinell tensile equivalent between 300,000 and 325,000 pounds per square

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A paper presented at the Pittsburgh Sectional meeting, May 25-27. The author Wallace B. Crowe, is armor plate metallurgist Homestead Steel Works, Munhall, Pa.

inch. Ground tensile tests were made from several of the specimens, but the results of check tests showed them to be so erratic that they were of little value.

Masses ranging from 12 to 13 inches in thickness, from one to several feet in width and from 5 to 20 feet in length, out of which the previous specimens had been obtained, were water quenched from tempertaures which were determined as the result of much previous experimentation. Test coupons were then broken from these large specimens, presenting a fracture about 1½ times the thickness of the piece from its end, and practically the same or a greater distance from the edge. The fractures presented a vastly different appearance when compared, as might be expected. These may be classified as follows:

Type of Steel	Appearance of Fracture
Plain Carbon	Fine granular near surface gradually coarsening to medium fine grain near center.
Nickel-Chromium Chromium-Vanadium	Porcelainic appearance 3 to 4 inches from surfaces.
Nickel-Chromium-Molybdenum	Semi-porcelainic internal appearance.
Chromium-Molybdenum	Similar to plain carbon steel although somewhat coarser.

Further examination revealed that those steels showing porcelainic or semi-porcelainic fractures were untoolable at any location, the toolable limits of these steels having been equivalent to 70-72 scleroscope. The plain carbon steel and the chrome molybdenum steels were each toolable at any location, the latter being the more so The most important characteristic observed was, that the plain carbon steel showed a greater falling off in hardness between the surface and the center than did the chrome molybdenum steel, the former showing a Brinell tensile equivalent of 180,000 to 120,000 pounds per square inch, while the latter showed 140,000 to 130,000 pounds per square inch.

The chrome molybdenum steel showing unusually low hardening properties in mass for an 820 degree Cent. quench was investigated more exhaustively. Two more large specimens were quenched from 875 to 1050 degrees Cent. respectively, the first having been quenched from 820 degrees Cent. The three sets of fractures were so similar as to be indistinguishable. Hollow-drill tests were drilled with ease through the thickness of each, and were Brinelled each inch of length of test bar, showing a variation of not greater than 15,000 pounds per square inch. Tensile bars were drilled longitudinally, parallel with and four inches from the surfaces. The results were surprisingly close, the tensile strength, the elastic limit and elongation varying no more than 2½ per cent and checking the previous Brinell tests. The actual tensile strength ranged from 133,500 to 137,000 pounds per square inch. Specimens taken from near the axes of the masses, and examined under the microscope, revealed that the masses which had the deepest chill showed the finest microstructure, after a drawback heat treatment.

The point which these experiments emphasize is that little relation exists between the physical properties of small and large masses, and that the heat treatment suitable for small specimens cannot be depended upon as a criterion for the proper treatment of large masses, except in a general way.

The large specimens above described were subsequently drawn back

at certain temperatures to produce approximately 20 per cent elongation in 2 inches and pulling tests were then made. The results of these tests showed that the outside-inside differential had practically been reduced to nil, and that the physical properties descended in about the same order as their respective chill depths, there being a great difference between the extremities of the scale. Specimens from the same types of steel were then subjected to air treatment, being air cooled from above AC3, and it was again found that those types which were susceptible to deep chill were untoolable, while those which had little or no chill after the water quench, were machineable. The untoolable specimens were drawn back to obtain approximately 20 per cent elongation in 2 inches, and their physical properties were far superior to those of the non-deep-chill type having had a water quench and a draw. Therefore, it may be necessary, in order to meet certain physical requirements, to employ those types of steel which are more susceptible to hardening. Where the mass is of such a shape as to render water quenching a hazard on the lower types of steel, the operation may be rendered far more safe by using the higher type steels with a less drastic quenching, and at the same time obtain superior physical properties.

The influence of sonims has an important bearing on the subject. It is the writer's opinion that the evil influence of sonims has been over estimated without due consideration of the nature and extent of the same. It has been his experience to examine microscopically steels which had shown excellent service tests, and which revealed considerable quantities of sonims. Previous to these examinations the writer had been very much opposed to such a condition but these service tests revealed the fact that sonims are not as detrimental as we have believed. Numerous specimens have been examined which have failed in service and which were practically free from sonims and would clearly come under the classification of clean steel. The presence of sonims therefore could not have been the cause of failure. In reviewing these investigations of sonims, the writer believes that the nature of their distribution is the important phase of the subject. Where the foreign matter is uniformly distributed in tiny particles and there is no continuety of arrangement, it has been found that the steel will usually pass normal requirements, but where the foreign matter occurs in agglomerations which would cause definite laminations and these arranged in a line of continuety, even though a large percentage of the steel appears to be clean, ordinarily a component made of such a steel could not undergo severe treatment without serious developments.

Where a highly specialized product is to be forged or rolled, and later heat treated to obtain extremely high hardness values, such as 100 to 125 sclerosocope, the steel should approach the highest degree of freedom from sonims and blowholes. Such defects may cause the rejection of the entire heat for the purpose intended.

Hot-top iron molds, having a section of 2 to 2½ times that of the ingot and preheated between 300 and 400 degrees Cent., will further improve steels susceptible to cracking.

Blowholes in nonwelding steels are quite similar to sonims in their effect on heat treatment, and after forging or rolling are almost indistinguishable from them even with the aid of the microscope. Where such conditions are known to exist the greatest care is necessary in

the heat treating operation, especially if the requirements demand a water quench. This is especially true where the sonims exist in laminations after rolling or forging. Laminations interfere with the uniform conduction of heat through the steel, which during the stage of rapid cooling is a very important consideration. High local strains are consequently set up in that region of the mass least able to withstand those strains, and where allowed to cool too slowly, may result in the immediate rupture of the piece. Where strength and toughness are required, a mild quench slightly below color may often save the piece and produce surprisingly good results. In such a case, however, an oil quench would be preferable with less internal strain being set up due to retarded cooling. Where the oil quench is not available recourse may be had to the hot water quench, the steam performing the two-fold function of heating and agitating the water.

The points discussed cover a large number of the heat treaters problems, for if the designing engineer has given due consideration to the heat treating problems, the proper composition has been selected, the steel well made and the fabrication properly executed with reference to the preheating temperature, the temperature at which it was worked, and the temperature to which it was cooled, the heat treater will find his worries very much reduced.

Assuming that the heat treating appliances are suitable, the heat treating problem resolves itself into two phases, the treatment of steels responsive to simple though perhaps drastic treatment, and the treatment of steel requiring mild complex treatment. In the majority of cases there will be a combination of these two conditions with the former predominating and where there is a similarity of the product and a large number to be treated, the modus operandi will be largely governed by the results of the first several trials. If the percentage of acceptance is high, it would be the best policy to pursue this method of treatment, resorting to a more complex treatment on that portion of the product which failed to pass test. If, on the other hand, only a small percentage passed the test on the simple, drastic treatment, it would be advisable to swing the treatment entirely to the more complex, until such a time as it might be deemed advisable to repeat the more rapid, drastic treatment with the purpose of obtaining high percentage acceptance on first treatment. Experience has shown that where possible, it is advisable to maintain a uniform, standard treatment, thereby being better able to operate on schedules which may have to be worked up to, several days in advance. By doing this, shop complications and much loss of time may be avoided.

The influence of mass on heating has been pretty thoroughly discussed during the last few years, and therefore an involved discourse on the subject will not be entered into at this time, but in passing it may be noted that there has been a tendency to underestimate rather than overestimate the importance of the duration of heating time to obtain complete saturation. Complete saturation is one of the most essential requisites toward good heat treating, and prolonged soaking is far preferable to incomplete saturation. A good empirical rule that has been found to be quite satisfactory, where the mass has a length and width several times that of the thickness, is to allow 1 hour per inch of thickness for heating to the desired temperature, and 2/3 of

an hour per inch, for saturation. Where the mass is a green casting cooled to atmospheric temperature, internal strains may exist of such magnitude that great care should be exercised in heating the first 200 or 300 degrees Cent. The character of heating should approach that of saturating to relieve internal strains and get the metal beyond the extremely brittle stage. Masses forged or rolled, while they may have as great or greater internal strains than castings, the better able to withstand those strains, owing to the mechanical refining already obtained, and the rate of heating may be somewhat more accelerated in the early stages. Shop or mill practice generally permits a rolled or forged mass to be charged for treatment before it has cooled down to the brittle range, in which case the early heating may be forced somewhat, with safety. Where the section is isometric and the length is several times that of the diameter the period of heating and saturating is about ½ the time above described for oblong cross sections. Where the 3 axes are practically equal, the time of heating and saturating is again reduced about one half. These rules are not strictly according to formula, but have been found by experience to be a safe general guide.

While the lag in heating is practically the same as the lag in cooling, the effect of lag in heating is to a great extent taken care of by the duration of saturation. The lag which occurs during accelerated cooling cannot possibly have any compensating influence corresponding to soaking in heating, and it is in this respect that the influence of mass in cooling presents a far greater problem than does the influence of mass in heating. It is for this reason that, where this lag may interfere with the internal physical properties demanded, the greatest judgment should be used in the selection of the composition least susceptible to the influence in this lag. The effects of this lag, however, may be somewhat overcome by increasing the temperature over AC3 with the increase of mass. The lag then takes place above the critical range so that in passing through the critical range the steepness of the thermal gradient of the center of mass has somewhat approached that of the exterior of the mass. This is done at the expense of the grain size, but the physical properties of the mass as a whole are superior to those where the mass is treated at the theoretically correct temperature.

Where the physical properties fail to satisfy after a quench, and drawback, and the cause appears to be a lack of grain refinement, recourse may be necessary to what has been termed a stepping-down treatment. Where the grain size is very large it will be found that the grain refinement will require an unreasonably prolonged soaking if the temperature is only slightly above AC3. It will also be found that if the temperature is raised 100 to 125 degrees Cent., the grain size temperature characteristic will be obtained quite rapidly. The grain size will be found to be much smaller than originally, but perhaps coarser than desired. If this is the case one or more intermediate treatments may be employed. The increased rate of change of grain size with the temperature is probably analogous to the cementation process in which the rate of diffusion of the carbides is much accelerated by an increase of temperature over AC3. The mass may be quenched after the various steps of heating if the material can stand it, but the general practice is to quench only the last 1 or 2 steps.

Masses of irregular section which tend to develop quenching cracks

in the thinner sections, present a problem which requires much study and experience. It is often necessary to retard the rapid cooling of the thinner section by the application of some insulating material, such as sheet asbestos, sodium silicate and asbestos compounds or even ordinary yellow clay with wire reinforcements, or any material which will more equalize the rate of cooling and reduce the local strains. The mass is generally cooled in the bath to a point, where when removed, the internal heat will reheat the surface to 125 to 350 degrees Cent., depending on the final hardness required. The mass is then ready for whatever drawback experimentation is desired.

It has been the purpose of this paper to point out some of the contributary causes of failure which should not be chargeable to poor heat treating, and to touch on some of the difficult points in the heat treatment of large masses. The writer appreciates that there is a growing co-operation between the designing engineer, the steel manufacturer and the heat treating engineer, and feels that the Amrican Society for Steel Treating and other engineering societies deserve their share of credit in working toward this end.

Discussion of Mr. Crowe's Paper

MR. GREEN (Philadelphia): The speaker made reference to quenching in hot water if oil was not available. What was the temperature of the hot water?

MR. CROWE: Approximately the boiling point. We have tried it at different temperatures. It is only a question of a short time before the water is heated to one hundred degrees. I don't believe it will produce as good results as oil but if you don't have oil it is far better.

MR. GREEN: The particular reason I asked that is that I had an experience sometime ago in going into a shop where they were quenching in cold water, and found considerable quantities of their material cracking. Then they changed to hot water, at 110 degrees, and the material seemed to have greater depth of hardness than when quenched in cold water. That was two years ago. Well, the other day, or quite recently, I was at that plant again and I asked them whether they were using warm water and they said yes, that they would not go back to cold water.

MR. CROWE: Of course it is difficult to maintain the temperature of the water constant. I am thinking of masses of twenty, thirty, forty or one hundred thousand pounds. That is what most of them do not have experience with.

I experimented with various temperatures, beginning with iced brine and every twenty degrees above up to the boiling point I found there was a tendency to get soft spots when immersed in water near the boiling point, as shown with the scleroscope and microscope.

MR. I. E. WALTON (Pittsburgh): I would like to ask Mr. Green whether he has tried cold water in comparison with hot.

MR. GREEN: This was an plates that had to be uniformly hard, and the hardness was more uniform when quenched in 110 temperature bath than when quenched in baths at temperatures around forty or fifty degrees Fahrenheit.

MR. CROWE: Well I found there was little difference between ice brine, and up to 60 degrees Cent. But as you get up toward the boiling point there was a greater tendency to develop soft spots, which may be quite serious and might spoil the mass.

MR. MORGAN (Pittsburgh): In your experience of the treatment of large masses, have you run into any instances where the shrinkage stresses developed and caused fractures, complete failures, or shattering of the steel?

MR. CROWE: Yes sir, that is almost the biggest problem we have and that is the point I brought out with reference to protections to more nearly equalize the rate of cooling. A large part of my experience has been with spraying, which is probably the most rapid cooling method known and unless due regard is taken in protecting portions cooling most rapidly, they will be cool long before the balance may be cooled down to loss of color, with the possibility of the coldest portion being ruptured. A careful study must be made of the balancing effect of protections.

DISCUSSION OF PITTSBURGH SECTIONAL MEETING PAPERS

FOUR of the six papers which were presented at the Pittsburgh Sectional Meeting held May 25-27 at the Bureau of Mines, Pittsburgh, Pa., were published in the May issue of TRANSACTIONS. The purpose of preprinting papers which are presented at either the annual convention or the sectional meetings is for the purpose of stimulating discussion, as it is realized that a large amount of valuable information is brought out through a well organized discussion. In order that members may have the opportunity of receiving papers before they are presented the policy has been adopted of publishing as many meeting papers as it is possible, prior to their presentation. This policy was in force at the time of the New York Sectional Meeting and as a result a large amount of splendid discussion followed the papers presented. The same is equally true of the discussion which followed the presentation of the Pittsburgh papers.

The discussions of Prof. F. F. McIntosh's paper entitled "Fiber in Iron and Steel" is appended to his paper which appears in this issue of TRANSACTIONS. Likewise the discussion of W. B. Crowe's paper entitled "Factors Influencing Mass Heat Treatment" is published in this issue of TRANSACTIONS with its discussion appended.

The discussions which follow are in the order of their presentation at the meeting. Each of these papers may be found in the May issue of TRANSACTIONS. The titles of the papers which are discussed in the following pages are:

"A Discussion of Impact Testing Methods and the Results Obtained."—by John M. Lessells.

"The Abrasive Qualities of Plain Carbon and Alloy Steels."—by A. M. Cox.

"The Importance of the Proper Heating and Cooling of Steel."—by John A. Succop.

"The Change in Dimensions of High Speed Steels in Heat Treatment."—by Marcus A. Grossmann.

Discussion of Mr. Lessells' Paper

MR. E. E. THUM (New York): A great many of us will not disagree that impact testing will become of considerable importance, if it is not already so, but there are yet some who fail to see that the impact test indicates infallibly variations in quality of the metal. In other words, many American metallurgists will decline to admit that the impact test is competent and reliable. Does the impact test do anything that can be depended upon? Are the variations which it shows due to actual variations in the metal, or to variations in the action of the testing machine or to a combination of both? Mr. Lessells has just shown a curve indicating impact strength of a certain steel after various heat treatments. That curve showed a peculiar drop at a certain temperature range, corresponding to "notched brittleness." Is notched brittleness anything, and if it is something, what is it?

There is a general tendency in the art of testing materials to get away from "omnibus" tests in favor of tests which determine one particular property. In other words, we seldom take a particular casting or forging and bend it under a hydraulic press, and observe its action. We would much rather have test bars cast from such a fabricated piece and pull them apart in a testing machine. In consequence, when testing the strength of rivets, we seldom rivet up a joint and pull it apart. We depend rather on getting our information as to quality from simple shear or tension specimens, and then try to translate those results into what we may fairly expect of the performance of a riveted joint. It seems to me that the impact test is a reversion to the omnibus test, since no one is quite sure of the nature of the resulting action when a notched piece of metal is given an overpowering blow, causing it to break in an infinitesimal time.

Furthermore, there is yet no general agreement as to the proper way to make the test. The Frenchmen will tell us how good the Charpy test is, and the Englishman will tell us how good the Izod test is. Some American metallurgists are free to tell you how bad they both are! Apparently a great need is accurate information, or wider publication of such information as exists, on how closely a well designed impact machine can reproduce results on material which we are sure is quite uniform by knowing the details of its manufacture and by exhaustive testing in other ways; and on the other hand, how the same test works on material which is known to be non-uniform. Suppose, for instance, that we have a considerable volume of most excellent, uniform metal, and we test this metal in various directions by various machines. Now if the curves which one might draw against any particular property of this metal plotted as a straight line, or nearly so, and the impact results, (when made by several accepted machines) would parallel each other, and would do so, not once but every time, then the objectors would have to admit that the impact test as perfored in the correct way is a good test. If, however, the impact curves would not parallel, but would cross each other and wander around at random, then it would seem to me that it is up to the proponents of impact testing to explain why these various methods do not agree among themselves. It might even be that one steel would be passed if tested by a certain machine in impact, while another impact machine would reject that same steel.

I have in mind some results which have been recently published by the Joint Committee on the influence of sulphur and phosphorus in steel. This committee was appointed by the American Society for Testing Materials,

and contains representatives of various steel-making and steel-using organizations. It was convened primarily to discover whether war time limits of sulphur and phosphorus could be safely retained.

Their first report covers the effect of sulphur in rivet steel. Fourteen heats of steel were made, under close observation, by the Carnegie Steel Company, in a 75-ton basic open-hearth furnace. The composition of the steel was held quite constant except for sulphur, which varied in each one, ranging from 0.02 per cent to 0.18 per cent. Altogether over 5000 physical tests and 1000 chemical analyses were made, and in general the evidence is that the material as received from the mill was uniform and first-class in every respect. These steels were sent to the investigators in the form of one-inch rivet bars and one-inch slabs. They were tested as they were received, after an anneal at 940 degrees Cent. for half an hour (cooled in the furnace) and thirdly, after a quench from the same heat. Tests were made at the Watertown Arsenal and at the Annapolis Naval Engineering Experiment Station.

In general the reports from the two different laboratories agreed quite well. The ordinary tensile test showed that sulphur had very little influence. In other words, when plotting tensile strength, yield point, elongation, etc., against sulphur content, the curves were practically horizontal, and individual heats varied but little from the median line. From all tests other than the impact test, the material was shown to be extremely good, and it undoubtedly was uniform. As before mentioned, these physical tests all showed that sulphur had practically no influence within the limits of 2 points and 18 points.

Now let us look at the impact figures, and see whether they agree among themselves, or agree with the fact that chemical analyses and other physical tests lead us to believe that we are working on uniform metal—that is, metal as uniform as we can reasonably expect tonnage material to be at the present time.

Fig. 1 shows impact tests on the bars as received. The Izod test shows that out to a little beyond 6 points the impact strength is 115 foot pounds or better, but with increase of sulphur to 0.18 per cent it lowers to 80 foot pounds. In other words, there is apparently a sharp reduction in Izod impact as sulphur goes beyond 6 points. The Charpy test on the same bars shows practically the same thing. It should be noted that each point on these curves represent the average of 16 tests made by quite competent investigators. However, there is a third curve showing the properties as determined at Annapolis by a method called "impact shear" where an unnotched rectangular bar is broken. Eight tests were made on each heat. The point is clearly brought out by these curves that impact shear is 40 foot pounds for low sulphur, and remains at that figure *despite increasing sulphur.*

Fig. 2 shows impact tests on rivet bars after annealing at 940 degrees Cent. Note again that the impact shear curve is practically horizontal and has not been lowered very much. Also note that the Izod values, which before annealing were up beyond 110 foot pounds dropped off to about 35 foot pounds. Now we don't ordinarily expect a short anneal, at a moderate temperature, to cause a great deal of brittleness, and yet here is a test, which is supposed to give a definite measure of toughness, showing a tremendous increase in brittleness *after a heat treatment which should ordinarily toughen.* Not only is the Izod impact down 50 or 60 per cent, but the Charpy values are down 80 per cent. Also note that the Charpy curve is now practically horizontal. Furthermore, note how erratic the Izod tests have become. They

do not seem to parallel variations shown in either of the other curves. Especially heat T runs up to about 66 foot pounds for no apparent reason. Furthermore, at heat J, the Izod curve has a peak and the Charpy curve has a slight valley. Thus the correspondence of these curves is very poor.

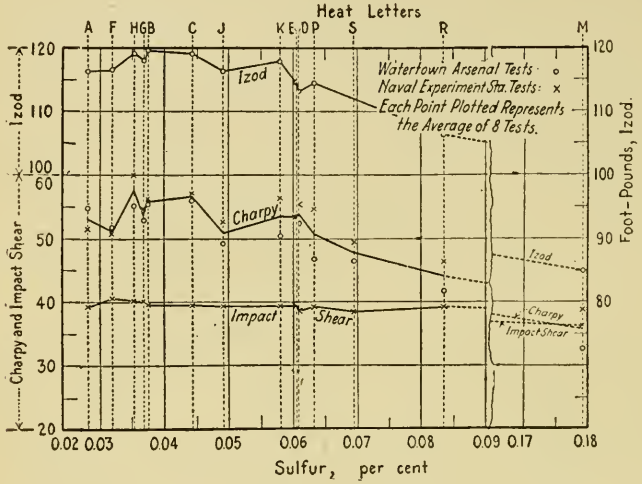

Fig. 1—Impact tests made by Charpy and Izod machines on bars as received.

Fig. 3 shows the rivet bars after quenching from 940 degrees Cent. This heat treatment actually raises the impact value—it is rather a new idea that quenching increases toughness! The Izod results again are erratic, there is a pronounced dropping off, however, at 6 points of sulphur, as was

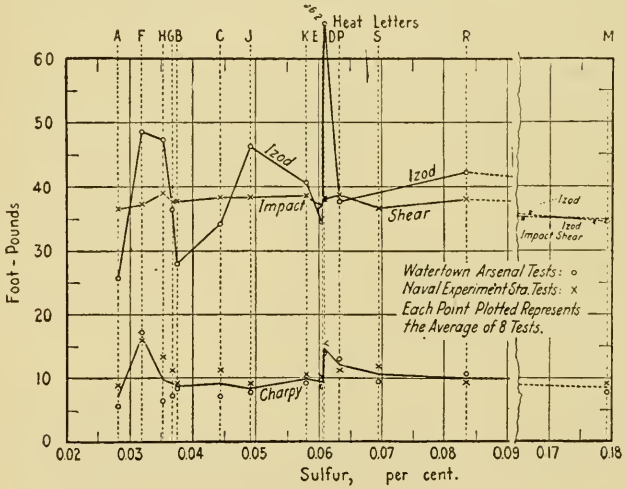

Fig. 2—Impact tests on Rivet bars after annealing.

noted in the bars as received. Impact shear for the third time is horizontal. Charpy results drop off with increasing sulphur. Altogether there is very little parallelism in the curves.

Fig. 4 shows the same steel rolled to slabs one inch thick. From these slabs impact specimens were cut from edge to edge. In one case the hammer

swung parallel to the edge of the slab, and in the other case perpendicular to the flat surface of the slab. However, in both cases the specimen was broken parallel to the "grain" rather than across the "grain." In other words, you can hit against either surface of an impact bar cut across a flat slab, but

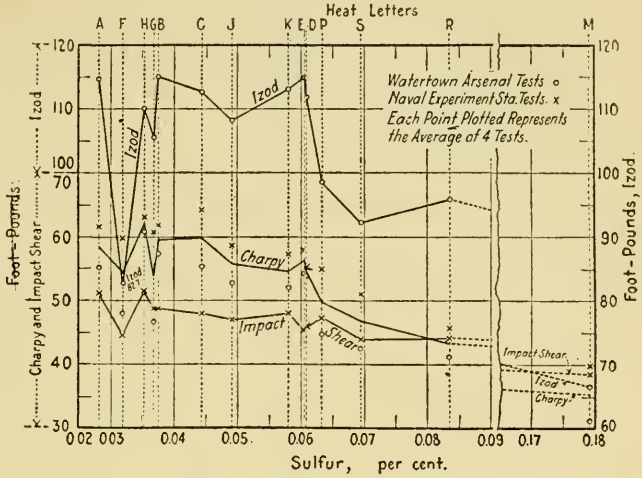

Fig. 3—Impact tests on Rivet bars after quenching from 940 degrees Cent.

in any case you will be breaking the specimen with the fibers. Now it would seem that the values in these two cases should be fairly close. In any event if one particular heat shows high impact in one direction in the Izod test, it should also show high impact in the same direction in the Charpy test.

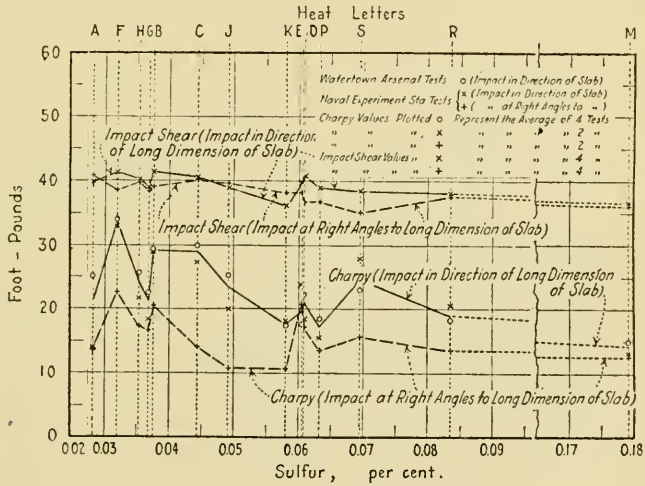

Fig. 4—Impact tests on Rivet steel rolled into slabs 1 inch thick.

As a matter of fact, the impact shear curves cross each other several times, whereas the Charpy curves drop off slightly with increasing sulphur, but they are very much more nearly parallel—that is to say, the peaks of the two curves correspond, and the valleys to the valleys.

Fig. 5 shows the tests made on the slabs after annealing 30 minutes at

940 degrees Cent., and cooling in the furnace. Comparison with Fig. 4 will show that the Charpy results have again been very materially lowered, whereas the impact shear is practically the same. As before the curves cross each

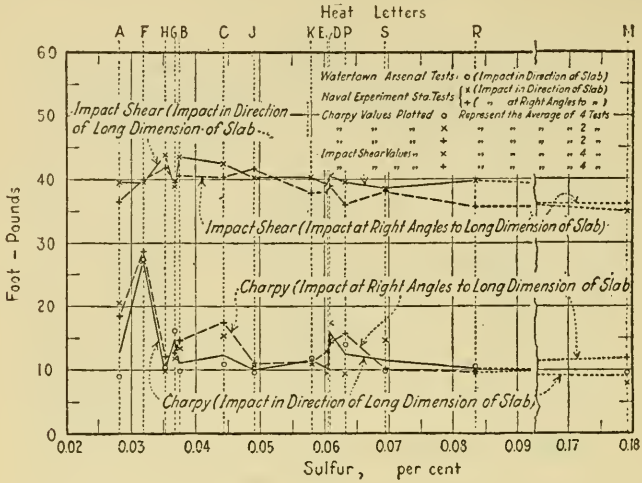

Fig. 5—Impact tests on slabs after annealing 30 minutes at 940 degrees Cent.

other somewhat at random, showing that there is very little correspondence in whatever it is that is shown by these two impact tests.

Fig. 6 shows the results on testing slabs after they have been quenched. The results are extremely confused.

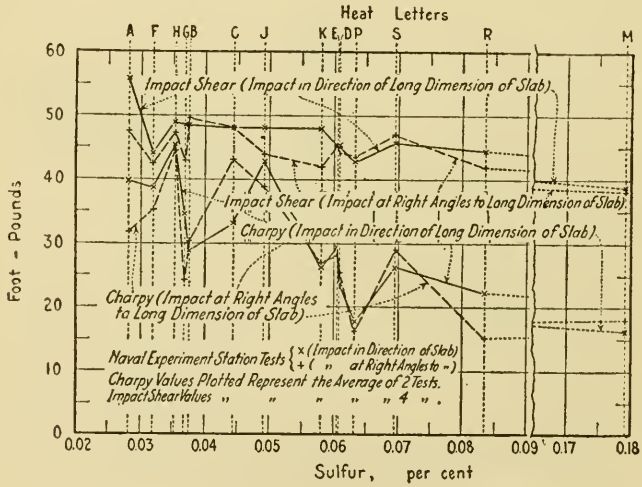

Fig. 6—Impact tests on slabs after quenching.

Table I shows some numerical values which have been scaled as well as could be done from the figures, after sketching in a median line which seemed to fit the observed facts. In general the table shows what has been said before, namely, that impact shear seems to be independent of sulphur and fiber in the bar as received. To a certain extent impact shear is also independent of heat treatment; a variation of only a few foot pounds is ob-

served after annealing or quenching. Izod tests were made only on the rivet bars, but you can observe a tremendous drop after annealing, a loss which was more than recovered after quenching. Question marks on the figures mean that the curves are so very jagged that one can estimate what the figure is no closer than four or five units. A most peculiar thing about the Charpy test is that if you break a slab after quenching it is stronger perpendicular to the rolling than parallel to the rolling. After annealing the relation is reversed.

Altogether the results of this very extended and extremely remarkable investigation indicate to my mind that the proponents of the impact test

TABLE I—IMPACT TESTS

	1-In. Rivet Bar; Broken Across the Fiber			5¼ x 1-In. Flats, Broken With the Fiber Impact Parallel to Rolling			Impact Perpendicular to Rolling		
As received	0.03S	0.06S	0.10S	0.03S	0.06S	0.10S	0.03S	0.06S	0.10S
Izod	117	114	103	.....	.....	.....	.....	.....	.....
Charpy	54	53	40	26	22	16	18	16	13
Impact shear	40	39	38	40	39	38	39	38	36
Annealed at 940 deg. C.									
Izod	38(?)	42	40(?)	.....	.....	.....	.....	.....	.....
Charpy	8.5	11	10	12	11	10	15	14	12
Impact shear	38	38	37	42	40	38	40	38	36
Quenched from 940 deg. C.									
Izod	112(?)	112(?)	90(?)	.....	.....	.....	.....	.....	.....
Charpy	62	54	43	40(?)	27(?)	17(?)	40(?)	27(?)	17(?)
Impact shear	50	47	41	50	46	41	47	45	42

will have to talk less about the curves they can draw by plotting impact results against any of the other chemical or physcial properties, and really tell us what happens when they hit a piece of nicked or unnicked metal an overpowering blow.

MR. J. J. SHUMAN (Pittsburgh): On this last slide (showing Mr. Thum's tabulation of rivet steels with varying sulphurs) I call attention to the figures for the Charpy test. I believe the Charpy impact method is a measure of the energy absorbed in cutting through the piece. If so these figures show clearly a comparison of a free-cutting metal with a metal that is not free-cutting.

You all know without my telling you that sulphur is purposely added in steel in order to impart a free-cutting nature. Accordingly any one in studying the tests that have been published by the committee on phosphorus-sulphur investigation, should bear in mind in comparing the Charpy results that they have developed the measure of free-cutting in the metal.

Observe the difference therefore that is caused by the addition of sulphur up to 0.06 or 0.08 per cent and note that it demonstrates clearly the value of screw stock, from the free-cutting or machining standpoint.

MR. LESSELLS: I think that if Mr. Lynch is here he will bear me out in what I am about to say. I very imperfectly tried to put before you on the second last slide, something from O. Lasche's publication showing that the speed of impact has got something to do with the results. I will say that it may be logical to compare the results of the Charpy and Izod but it is absolutely illogical to compare impact shear and any of these tests especially on low carbon material.

It has been demonstrated by Hadfield, and I think it is going to be

brought out by Mr. Lynch, that speed of fracture for impact is very important. Therefore if we are talking about any particular value that we get from an impact test, let us restrict ourselves to one particular machine.

With regard to the other question of notch brittleness, while I may say that notch brittle material may not be barred, if I could have two materials with the same elastic limit, I would prefer the material in constructional work which gives the high impact value—whether Izod or Charpy.

CHAIRMAN JOHNSON: Are there further questions on this paper?

MR. C. E. MARGERUM (Charleston, W. Va.): I would like to ask to what extent Mr. Lessells' tests indicate the effect of impact; that is, to what extent and in what direction the results are influenced by the fact that the load is imposed on the bar by means of the momentum of a ram, rather than by a mechanism which acts more slowly. I would like to know whether Mr. Lessells has found that the amount of energy required to break the bars was smaller when they were broken by impact than when the load was applied more gradually, or whether the reverse was true, or whether the results given represent the properties of notched bars irrespective of the method of applying the power.

In all the published results which have come to my attention in which the amounts of energy required to break notched bars by impact are compared with the amounts required to accomplish the same results by slow action, it has been found that with the single exception of bars of very coarse grained extra soft steel, more energy is required to break a notched bar by impact than by slow action. Do the tests under discussion confirm this observation or have exceptions appeared?

If more energy is required when the piece is broken by impact than if it is broken by slow action is not this contrary to the popular conception of the purpose of the impact test? I believe that the general impression is that impact tests measure brittleness under impact, that is, a deficiency of strength under impact as compared to strength under dead loads; but if in all cases but one the resistance to rupture by impact is greater than the resistance to standing loads, is it not likely to be misleading to refer to tests of this kind as impact tests?

MR. LESSELLS: I admit the error. It should be notched bar test really instead of impact.

Supposing you arrange bars small enough to get measures of the energy to bend them, then I am quite sure that would not be indicative or have any relation to the value you would have by actually notching the pieces. You can look upon a notch as a factor of safety. But as I have tried to indicate here, that impact and reduction of area has, or appears to have, a certain relation, then I think we could accept that a material which gives a higher Izod value is going to stand shock in service better than a material which gives a low Izod value. I don't know whether that covers the question or not.

MR. MARGERUM: I would like to inquire as to the appearance of the fractures. In a large number of tests made by Messrs. Charpy and Cornu-Thenard, in which many types of steel were tested, the appearance of the fractures, and the deformations of the bars were the same whether the pieces had been broken by impact or by slow action, except in the case of the very coarse grained extra soft steel, which was unique both in that less energy was required to break it, and in that the bars broke with a crystalline fracture and slight deformation of the metal bordering on the notch, when

broken by impact, while similar bars, broken by slow action took more energy, showed a fibrous fracture, and were much bent and deformed before they broke. It would be interesting to know whether Mr. Lessells' bars behaved in a similar manner. If this is true in all cases, impact brittle material may be detected with certainty by a simple hammer test and the so-called impact test is superfluous except as a convenient method of measuring notched bar properties.

MR. LESSELLS: I didn't know whether I made that point clear or not. I showed no photograph of a notch-brittle material.

MR. MARGERUM: Did you find that the properties of any of these samples were different when broken by impact from what they were when broken by slow action?

MR. LESSELLS: Oh yes, the rapidity of fracture has a lot to do with it, but as long as you keep the speed the same, as long as you keep that variable the same, your ground of comparison is sound.

Supposing, for the sake of argument, we are fracturing at the rate of twenty feet a second; as long as we keep twenty feet a second constant, it is quite a sound basis to compare. But the point that I indicated before was, unless that velocity is a given amount, it doesn't show up all these characteristics. So the thing I am trying to guard against is, if we are going to develop impact testing, let us have speed enough so that we will have all these variables cut out.

MR. C. B. DICKSEE (Pittsburgh): The British Air Board during the war issued several pamphlets on this subject inasmuch as they were confronted with considerable difficulty in reproducing tests when specimens were made rapidly and in quantities. The variations in the notch, particularly the radius at the bottom of the notch, had a great bearing on the results obtained. I also notice from Mr. Lessells' photographs that the depth of the notch was not uniform. In some cases I would say that the depth was 30 per cent greater than in others.

MR. LESSELLS: The depth of the notches appeared on the photographs that way, but at the works we can reproduce these depths of notches very accurately. You can't judge by the photographs. You see them at different angles and that masks the depth of the notches.

I think, however, that that is quite an important point. If we are going to introduce a dynamic test of this nature we must insure that we get and reproduce accurate notches. I think it can be done commercially with this proviso, that a proper cutter is used. It can be done— we do it.

MR. DICKSEE: Are not the different results obtained due to different types of notches.

MR. LESSELLS: That is why I say it is not fair to compare Charpy and Izod. If we are going to talk Charpy, let's talk Charpy, and if we are going to talk Izod, all right; but don't let's compare these values with shear values.

MR. KNERR (Philadelphia): Can you give us any information as to the behavior of low impact materials in service? That is, what does low impact really signify in practice?

MR. LESSELLS: There again I can't say very much on that. You see this form of testing was brought on by the war conditions more or less. It has been developed under war conditions and naturally under such we had not all the facilities for examining what happened to materials, but I would imagine that since an impact value is a measure of the grain

formation in materials, the one with the high Izod value is going to stand up longer in service than the one with the lower Izod value, all other things being equal.

MR. T. D. LYNCH (Pittsburgh): There is to be a symposiuum on impact testing of materials at the convention of the American Society for Testing Materials which meets at Atlantic City June 27th to 30th inclusive. The subject will be discussed under five headings, namely:

1. Resume of impact testing of materials and bibliography.
2. Machines and test specimens used in impact testing.
3. Standardization of machines and specimens for notched bar impact tests of metals.
4. Measurement of impact.
5. The significance of the impact test and its relation to other tests of materials.

This last sub-division will be discussed by Dr. F. C. Langenberg, Watertown Arsenal, who has given as much or more study to this subject as any one else. One entire session of the convention will be devoted to the subject of impact testing.

Referring to the slides that Mr. Thum put on the screen and which was commented on by several of the men present, I would like to point out one thing in connection with the chemistry of the steel referred to, covering the report of the joint committee on phosphorus and sulphur in steel. All of the steel so far tested is very low in phosphorus, under 0.02 per cent, and the discussion brought out here, should not be permitted to confuse our minds with a high phosphorus steel that may be high or low in sulphur. We have found from some personal tests which we have made, that steel, known as open-hearth automatic screw stock, having low phosphorus but high sulphur, gives us very good results on tests such as have been made by the phosphorus and sulphur committee, but where we have high sulphur together with high phosphorus we would expect a brittle material. There are so many complications in steel that it would be unfortunate if the report of the committee on phosphorus and sulphur in steel were construed to mean that high sulphur did not affect steel of any quality.

MR. ALLEN (Springfield): I am sorry Mr. Lessells did not make more mention in his paper of the Stanton test as it is one in which we place, considerable confidence. Assuming that the design is reasonably correct it is seldom that a piece snaps off short in service under impact test conditions, but, unless extreme watchfulness is exercised, failures will occasionally occur by fatigue either through faulty material or heat treatment. The Stanton, with its small impact blow repeated many times, alternately stressing the fibres in tension and compression, approximates more nearly actual operating conditions and hence the results obtained are a truer criterion of the ability of the material to resist fatigue and thereby stand up in service.

Where life tests can be made on finished parts, road springs for instance, we have found that the Stanton parallels the actual life results more closely than any other type of test we have tried up to the present time.

The machine is rather unique in that results can be duplicated with considerable accuracy which is not the case with most impact tests and the conditions of test can be easily varied as the height of the hammer drop can be altered to produce any stress desired. The Stanton machine, although of English origin, is now being duplicated in a somewhat modified form

by one or two of the American testing machine manufacturers; the test is well worthy of more consideration than is being given to it at present.

MR. LESSELLS: It might interest Mr. Allen to know that the Westinghouse Company intend to develop this form of test—this Stanton test. We also believe that it is indicative of the capabilities of the material to stand fatigue, and as I indicated very briefly, the fractures of a Stanton show all the characteristics of a fatigue fracture.

MR. W. J. MERTEN (Pittsburgh): In looking over the diagrammatic chart of Mr. Lessells, it seems to me it is very evident, since the Izod test does follow the reduction of the area curve, very closely, we should expect from an Izod test of high value a great deal of ductility of material, and it seems also to indicate high resilience.

I would like to point out some inconsistencies on the part of the British Institute tests. With a wide variation in ingredients, such as manganese or silicon, we should expect a difference in Izod values because of the increased values of silicon and manganese. I don't think any of us here will admit that 50 per cent higher silicon and 50 per cent higher manganese would not have a decided effect upon the Izod value of the steel in the tests described.

MR. LESSELLS: One slide is No. 14 and the other No. 15. Show them again, please.

Now, here, if this is true as Mr. Merten suggests, that the tempering temperature has no bearing on the change in physical properties which obtains, then the next thing I am going to say is that the silicon and manganese limits should appear in all material specifications.

MR. MERTEN: What I wanted to point out principally was I don't believe the quenching temperature of 30 degrees Cent. has an influence in the change of properties there, because in both cases you will be in the solid solution range at 870 degrees Cent. as well as at 900 degrees Cent. But the silicon as well as the manganese, being deoxidizing agents and alloying elements, produce an entirely different texture in the steel. And I think the Izod test is of value in showing up this particular condition.

CHAIRMAN JOHNSON: Is there further discussion?

MR. THUM (New York): There is considerable emphasis made on the point that the Izod parallels the ductility as determined by tension tests. I have no doubt that is true for the steel in question, but I would like to point out that in the sulphur investigation to which I referred, such is not the case. The rivet bars, as received showed that sulphur has very little effect on ductility, as determined in the ordinary tensile machine.

I really believe that the question about notching raised a minute ago is a good one. Engineers and constructors do not put notches into their machines if they can help it. Therefore a steel maker who is asked to furnish material for a certain impact value, could rest his case on the impact shear, and in the case of rivet bars for instance, the impact shear would give excellent results with high sulphur.

Consequently, it seems to me it is up to either this Society or some other society who are interested in the subject, to determine just what notched impact means, and what it can be used for.

Discussion of Mr. Cox's Paper

MR. E. E. THUM (New York): I would like to ask a question. Fig. 11 in the paper shows a microstructure of case hardened steel. I would judge that the caption there is incorrect inasmuch as that structure is characteristic of carbonized material before hardening. I doubt if you would get high hardness out of such a structure. The same is true of Fig. 12. Were those taken before hardening?

MR. COX: No, they were taken after hardening. That was the hardened structure.

CHAIRMAN BOYLSTON: The two illustrations in Fig. 11 have apparently been reversed somehow. The coarser grain corresponds to the single treatment and the finer grain to the double, does it not?

MR. COX: The finer grain is the double heat treatment.

MR. J. M. LESSELLS (Pittsburgh): First I want to say that Mr. Cox ought to be complimented on a paper of this nature, because it is something new. It is a new way to show an old subject.

My first question is: Was the machine checked up by running a large number of tests on material of a similar Brinell? In the variables you have shown the same material with different Brinell hardnesses.

MR. COX: That is what we did when we picked out the 555 and 444 and 302 range for each of the hardened steels.

MR. LESSELLS: The same material with different Brinell hardnesses and the same Brinell hardness for different materials?

MR. COX: That is practically what I have given in the paper. For instance the plain carbon steel—0.50 per cent carbon, that was shown in the 555 range, the 444 range and the 302 range.

Now as far as different steels go, in the chrome nickel, the parallel steel was also shown in those three ranges, which would take care of both questions. And as far as other tests are concerned, we have been making tests on the machine over a period of at least five years, so that when these tests were taken for this paper, comparison was made between the results we got on these test pieces and the test pieces that had gone before. They checked.

MR. LESSELLS: The question is, how far a machine of this nature is able to duplicate results? You have four steels here which show a very peculiar relationship. For instance, in the summary, you say the greater the density and hardness, the greater the abrasive resistance. I think that is one of the conclusions.

Now the Brinell tests do not show abrasive qualities, but a denser material; I mean, a material with a Brinell of 444 would be a more dense material than a similar material with a Brinell of 200, wouldn't it?

MR. COX: That is a question that has not been definitely proven.

MR. LESSELLS: If that is so, if the material increases in hardness with increase in density, then there ought to be some relation. The results evidently conflict there.

I would like to ask what provision was made to insure that the surfaces were all alike?

MR. COX: After each run you would naturally have a sort of powdery surface, and the main rolls were cleaned off and the test rollers were cleaned off in ether.

MR. LESSELLS: Run at the same speed?

MR. COX: Same speed, and weighed on the same balance.

MR. LESSELLS: This paper really raises a question of vital importance to engineers in general. For instance, it has always been my experience that running a case hardened steel pin in a case hardened bush, is bad practice, but to run a case hardened steel pin in a tool steel bush gives decidedly better results.

MR. COX: We have found that various combinations work out better than others.

There is a certain combination that worked out very nicely and they received great wear results from it; that is, for the driver to be Hadfield manganese steel and the driven cast iron, both of them comparatively soft materials, and they got very good wear results. Therefore, that brings out another point that should bring forth investigation along the line of making a comparison between various types of steel and operating in the same identical service in different combinations, in order to bring out suitable steels for each service.

Now if you will bear with me, during the war period we were hard pressed to get out a large order of street car railway pinions, and the only steel that was available was a chrome nickel steel. Approximately 500 pinions were made up of this chrome nickel steel and they averaged in hardness from 444 to 500 Brinell. They went into service and stood up approximately between 10,000 and 20,000 miles, whereas, in the same service the specially brine heat treated pinion gave a service of between 50,000 and 60,000 miles, which bears out the idea of investigating different combinations and investigating different services.

There has been very little published along the line of abrasive resistance, because when I started to write up this paper I visited the Central Library at Carnegie Institute, and about the only item I could find on abrasive qualities was in grinding wheels. That naturally didn't apply to this paper. So that I hope this will be a starting point, although we really can not draw real conclusions from what we have done. But it is to be hoped that a more general investigation will be started along the abrasive resistance of metals.

MR. W. B. CROWE (Pittsburgh): There is one term that is very confusing with reference to hardness, and that is the application of the word "density." Just what is meant by the term, as applied to hardness? Does it have any reference or relationship to specific gravity, or just what is meant by it. It has always been my conception that a hardened steel is less dense than a softened steel of the same kind. So I have often wondered what was meant by the term "denser structure" with increased hardness.

MR. COX: We always understood the term "density" was used in more of a specific gravity sense, and hardened steels we have always found to be denser than the untreated.

MR. CROWE: I have heard of investigations that have been made on steel, in the martensitic and pearlitic phases, where a lower specific gravity was found on the martensitic steel, approximating one per cent, which is contradictory to the ordinary term as applied.

MR. COX: That is probably due to martensite formed in tension. It might be, if you have a piece that is martensitic, that you would have lower specific gravity than with a piece that combines the two.

MR. GROSSMANN (Charleroi, Pa.): It seems to me that the term

"density" is more of a colloquialism which refers to the appearance of the fracture of a piece of hardened steel. There is no question at all that a piece of hardened steel, in a martensitic condition, is less dense with regard to specific gravity than a piece of annealed steel. You will have a much finer grain, a "closer" grain, and that is where the term "more dense" has come from, I believe. I believe in practically all cases, socalled dense steel with a fine grain is really less dense in the sense of the specific gravity.

MR. MORGAN (Pittsburgh): This test is a very interesting test, and if I might be pardoned, I would like to ask you a question. I like to compare. As I understand it, the two large rollers are cast manganese steel. From the sketch I would judge that perhaps the surface, the contact surface, of each individual one was something like four times that of your test roller?

MR. COX: Surface? The rollers were three inches in diameter and the test roller was one inch. That would be 3 to 1.

MR. MORGAN: And they would divide the slip perhaps equally so that you would have about 6 to 1. I wondered how many tests you could run on those manganese steel rollers, which would give some conception of the relation in resistance to abrasion of the test pieces in comparison with manganese steel?

MR. COX: In comparison with manganese? Well, the only way there would be is to make up the manganese steel, in the same form as the test roller itself, unless you ran, say, the same test roller for quite a period of time and then dismantled the machine and weighed up the manganese large rollers.

MR. MORGAN: The question might be answered, by how long these manganese steel rollers stand up.

MR. COX: Well, they were newly ground when we started that series of tests and they wore down approximately a thirty-second of an inch when we had finished.

MR. MORGAN: The test rollers are prepared by grinding?

MR. COX: By grinding. First they are heat treated, leaving about ten thousandths on the diameter, for grinding, so that in case there was a slight decarbonization in heat treatment that would be eliminated.

Discussion of Mr. Succop's Paper

MR. HOFFMAN (Pittsburgh): What bearing would rapid or slow cooling in hardening have on the quality of the block, and how would it affect the curves such as you have shown, say with one cooled in oil, one cooled in water at 100 degrees Fahr. and one cooled with a spray?

MR. SUCCOP: The water cooled block is going to contract faster than the oil cooled block.

MR. HOFFMAN: Would you consider quenching in oil superior to quenching in warm water?

MR. SUCCOP: I think that the warm water approaches the oil and it depends upon the desired results. If you want hardness you want a quick quenching medium. The oil will give greater ductility after quenching than the water.

MR. HOFFMAN: I had reference to a heat treated block where you have a Brinell hardness of 350 and perhaps would be compelled to use a draw back. If you have a block 18 inches square and put it in oil, would you

cool that block evenly all the way through, so that you would have a heat treated block, with a Brinell hardness of 350 at the center?

MR. SUCCOP: We have found in large die blocks, which were quenched and cut in half, the scleroscopic hardness from the surface to the center, was found to vary only 5 points.

MR. HOFFMAN: Cooling in oil?

MR. SUCCOP: Cooling in water.

MR. HOFFMAN: Could you have gotten the same results if you had cooled it in oil?

MR. SUCCOP: I don't know, we never tried it.

MR. JOHN J. CROWE (Philadelphia): Fig. 3 curve III which indicates the temperature at the center of the oil cooled specimen shows a sharp break at 1200 degrees Fahr. In Fig. 4 curve II a similar break occurs at 450 degrees Fahr. The break is shifted from the center position to a position 4.5 inches from the outside. How do you explain that?

MR. SUCCOP: You mean that the center cooled off more rapidly in the water cooled than in the oil cooled?

MR. J. J. CROWE: If you look at curve III on Fig. 3 the curve for the thermocouple placed at the center of the cube at 1200 degrees Fahr. after 38 minutes there is a point of inflection in the curve, it shows a sharp break. This same characteristic is shown in curve II Fig. 4 at 450 degrees Fahr. after 36 minutes. The point of inflection has been depressed 750 degrees Fahr. and has been shifted from the center to the position noted as No. II, 4.5 inches from the outside, half way between the center and the outside.

MR. SUCCOP: I cannot answer that.

MR. J. J. CROWE: That is something that may be worth studying. In doing some work several years ago on the temperature distribution in the head of a 90-pound rail, I placed one thermocouple just under the surface and another at the center and after heating to well over the critical range allowed the rail to cool in air. The outside cooled much more rapidly than did the center until the critical range was reached when there was an actual reversal on a differential couple indicating that the outside was slightly hotter than the center.

MR. HOFFMAN: Were your blocks, or eighteen inch cubes chrome nickel or plain carbon?

MR. SUCCOP: Plain carbon.

MR. HOFFMAN: I notice for the 18 inch block you use a 25 inch ingot. Would you consider that the proper proportion of reduction for all blocks?

MR. SUCCOP: That is not as much as is regularly given. But that is the way E. F. Law developed these curves. That is not of course as much as is regularly given, usually there is a greater reduction. I would say, rather than a 25 inch ingot, a 30 or 32 inch ingot should have been used for the proper reduction.

Discussion of Mr. Grossmann's Paper

CHAIRMAN BOYLSTON: We have a short written discussion from Mr. S. C. Spalding of the Halcomb Steel Company.

Chairman Boylston read the written discussion of Mr. Spalding which is as follows:

I was greatly interested in the data published by Mr. Grossmann on the change in dimensions of high speed steel in heat treatment. This is a subject worthy of considerable attention, but as Mr. Grossmann states, printed data on the subject is hard to find. It was surprising to me that the author found the steel to expand in hardening. It has been our general experience that a high speed steel will shrink in hardening. To confirm this statement, I give here some measurements made on a steel of the type of Mr. Grossmann's No. 18.

Two bars of high speed 7/8 inch in diameter were selected and two cylinders made from each bar, 13/16 inch in diameter by 3 inches long. The cylinders were carefully measured, then hardened and measured, then drawn and measured. The results follow:

	Length in Inches	Difference in Length in Inches	Diameter in Inches	Difference in Diameter in Inches
	Piece No. 1			
Before	2.9719	.....	.8122	.....
2200 degrees Fahr. in oil	2.9692	—.0027	.8112	—.0010
Drawn 1050 degrees Fahr.	2.9683	—.0036	.8113	—.0009
	Piece No. 2			
Before	2.9967	.....	.8121	.....
2250 degrees Fahr. in oil	2.9937	—.0030	.8111	—.0010
Drawn 1050 degrees Fahr.	2.9927	—.0040	.8111	—.0010
	Piece No. 3			
Before	2.9895	.....	.8120	.....
2200 degrees Fahr. in oil	2.9874	—.0021	.8114	—.0006
Drawn 1050 degrees Fahr.	2.9862	—.0033	.8115	—.0005
	Piece No. 4			
Before	2.9892	.....	.8122	.....
2250 degrees Fahr. in oil	2.9864	—.0028	.8111	—.0011
Drawn 1050 degrees Fahr.	2.9854	—.0038	.8111	—.0011

To see what effect the shape of the cross section would have, two pieces, one each of bar No. 1 and No. 2 were made up in tap sections 3 1/4 inches long, measured, hardened at 2250 degrees Fahr. and measured, then drawn at 1050 degrees Fahr. and measured. The results follow:

Bar No. 1
2250 degrees Fahr. in Oil—Drawn 1050 degrees Fahr.

	Length in Inches	Difference in Length in Inches	Diameter in Inches	Difference in Diameter in Inches
Before	3.2155	.....	.8101	.....
After hardening	3.2118	—.0037	.8088	—.0013
After drawing	3.2107	—.0048	.8083	—.0018

Bar No. 2
2250 degrees Fahr. in Oil—Drawn 1050 degrees Fahr.

	Length in Inches	Difference in Length in Inches	Diameter in Inches	Difference in Diameter in Inches
Before	3.2105	.....	.8094	.....
After hardening	3.2054	—.0051	.8083	—.0011
After drawing	3.2037	—.0068	.8079	—.0015

This shows No. 1 to have shrunk .0015 inch per inch of length and No. 2 to have shrunk .0021 inch per inch of length. This shows that the tap section which contains less metal apparently shrinks more than the solid cylinders. This in turn would indicate that temperature and length of time in the furnace would have an important bearing on the shrinkage.

It would seem that there must be something radically different, either in the condition of the steel or in the treating that would cause Mr. Grossmann's test pieces to expand and ours to shrink. Ours were preheated to 1750 degrees Fahr. in a wire resistance electric furnace, then transferred to a carbon plate electric furnace at the required quenching temperature, left until they were judged right by a high speed hardener, then quenched in oil. It would be interesting to hear expressions from members present who have had experience with high speed as to whether they have usually found it to expand or shrink.

MR. GROSSMANN: I am sorry to discuss this paper of Mr. Spalding's in his absence because I would like to ask him what I think would be the vital point in it, and that is regarding the protection of the ends. If those pieces hardened in an open furnace as he implies, were not protected on the ends, a certain scale would form which would either flake off or perhaps be removed or smoothed in order to make the measurement easier. I know of certain tests that were made on the same steel that I used in these tests, were treated in that way, and they apparently showed a shrinkage, but so far I have made probably fifty tests on steels of four different types—these three and a cobalt steel, high speed, and they all expanded without any exception. They were preheated to 1600 degrees Fahr. and then transferred to a high speed gas furnace at the temperatures at which the tests were run and left there in the neighborhood of 5 minutes and then quenched in oil.

MR. MERTEN (Pittsburgh): Mr. Grossmann spoke of formation of carbides on cooling and changes due to this formation. Doesn't he rather mean the precipitation of carbides instead of formation? I don't think carbides are destroyed or broken up by heating through any temperature except probably when heated to a liquid state. Doesn't he mean precipitation instead of formation?

MR. GROSSMANN: There seems to be considerable controversy on that particular point just now. There are two rather opposing views. One of them is that carbides and tungstides, or whatever they are, dissolve in atomic dispersion, and the other view is that they dissolve as a whole. In one case the formation, or precipitation of the carbides and tungstides would mean association of the atoms to form the molecules, and then an association of those molecules to form the larger particles.

The other view would mean merely that the molecules are preserved as a whole, while being dissolved in the matrix and that they merely associate to form the larger particles which are later visible under the microscope with higher drawing temperatures.

MR. MERTEN: I don't believe that volume changes indicate a molecular disintegration and atomic dispersion. I don't know whether these high sounding atomic dispersion theories have any bearing whatever on your problem.

MR. GROSSMANN: I think the question of whether they are in atomic dispersion or molecular dispersion has very little to do with it but the association of either the atoms or the molecules has a great deal to do with the accompanying contraction of volume.

MR. MERTEN: I have always been able to explain to myself and others the volumetric changes in the precipitation of carbides, and I think the twinning theory explains the volumetric increase in your structure. It makes it rather hard to see why a volume should increase by a formation of a chemical union between iron and carbon, if such a thing is possible, at this temperature. From that standpoint I think the precipitation of carbides is more plausible to the average man than another explanation.

MR. HOFFMAN: In summing up your paper, did I understand you to say that the proper drawing temperature at which you would have the steel retain its original dimensions to be 900 degrees Fahr.

MR. GROSSMANN: As far as these tests have gone, yes. The steel can be drawn of course at 900 degrees Fahr. and still retain almost all of its original high speed cutting properties, and yet at 900 degrees Fahr. it will be nearest to its original dimensions.

MR. GREEN (Philadelphia): I would like to ask Mr. Grossmann how deep were the holes and tappings that those bolts were sunk into to hold the pieces on the ends, and whether or not the holes being in the piece caused any differences in the measurements. That is, if you look at your Fig. 1, how deep were the holes drilled to put the bolts in?

MR. GROSSMANN: A half inch deep.

MR. GREEN: You took the measurement in the center. You don't think it could have affected the conditions one bit, having those holes there?

MR. GROSSMANN: I hardly think it could have affected it.

MR. THUM (New York): The discrepancy of the results in Mr. Grossmann's work and that of the Halcomb steel company seems to be great.

I happened to look up some work of Mr. Scott of the Bureau of Standards and he gives expansion curves that are very similar indeed to Mr. Grossmann's curves. There is a striking parallelism in that the quenched specimens are always larger in volume, than the annealed bar. On successively higher drawing of quenched bars he got a slight contraction followed by an expansion when the secondary hardness appeared. On even higher tempers (anneals) there is a sharp contraction. In other words, Mr. Scott's work of the Bureau of Standards seems to verify Mr. Grossmann's work as near as could be expected.

MR. HOFFMAN: A lot of the results depend on the method in which the samples were heated. The one which Mr. Grossmann used and the one used by Mr. Spalding may have been different, which would account for the variation in results.

MR. GROSSMANN: I can't say that I can see any reason why such differences in heating would have that effect.

MR. HOFFMAN: Your specimens were not subjected to the flame.

MR. GROSSMANN: They were heated in an open gas furnace.

MR. HOFFMAN: Your specimens were not heated in an enclosed capsule?

MR. GROSSMANN: No.

MR. HOFFMAN: The other was an electric furnace. Yours was a gas fire. It may have some bearing on the results.

MR. GROSSMANN: It may have, but I question whether, at that temperature the gas absorption would be great enough because the higher the temperature of a piece of steel, the less it is susceptible to gas absorption.

MR. COX (Pittsburgh): There is one point there. Your preheating was done at a temperature of 1600 degrees Fahr., and the Halcomb Steel

Company preheated at 1750 degrees Fahr. There is a difference of 150 degrees Fahr. and the rate of preheating would be greater in the 1750 degrees Fahr. than in the 1600 degrees Fahr. It might be possible that there is a difference in the types of the preheating and heating up for final quenching.

MR. GROSSMANN: Yes, but we have made a few tests in which the preheating temperature was as high as 1800 degrees Fahr. and we found always the same expansion.

MR. MORGAN (Pittsburgh): Isn't there a condition incident to the treating of any steel, that, if you please, may waive consideration of these supertechnical points?

When we cool a piece of steel in any medium, all papers that we have heard in the last couple of days have indicated that we do not cool the steel at a uniform rate from surface in. When we cool steel we find that we set up tremendous shrinkage stresses. You cannot have stress without a strain. The minute you set up shrinkage stresses you must have a change in dimensions that go with them, and when you draw or anneal or pass through any other operation in drawing, or whatever it may be, the shrinkage stresses and corresponding strains adjust themselves to each other.

So that the point I want to make is that the conditions of heating and the conditions of cooling and drawing, the intimate conditions, the detailed conditions, would be largely vital in affecting the final mass of the material passing through such treatment.

I would like to inquire if Mr. Grossmann thinks that would have any bearing.

MR. GROSSMANN: I think it might have a considerable bearing on large masses on account of the stresses that are set up in the steel due to the temperature gradient between the outside and the center. This has to do more with the normal thermal expansion because as a piece of steel is cooled, aside from these volumetric changes that we have discussed here, there is a normal contraction in cooling, and of course the outside tends to cool more rapidly than the center. The center, since it doesn't cool as rapidly as the outside, has a larger volume so that it induces in the outside certain stresses which might cause an expansion, a purely mechanical expansion, accompanying the tendency toward contraction. I don't know whether I make myself perfectly clear on that but I think you can readily see that if a large block of steel as in Fig. X is at a temperature of say 1800 degrees Fahr., and is suddently plunged in water so that it is caused to cool rapidly on the outside, then dimension A, we will say, where it is all exposed to the cooling medium, will tend to contract from the dimension A, down to one like dimension B, exaggerating it a great deal. The center, being much hotter, will naturally have a larger volume. It will have almost its original length equal to A and since this outside piece A tends to assume this length B and the center piece holds it to about this other length A, naturally there will be an intense strain on this outside, tending to hold it to its original length, and that might have a great deal to do with it in a large block. However, the center being hotter is more plastic and will yield more to the contracting force from the outside.

Whether it would have much to do with it on such a small block as this test piece, I rather question.

MR. H. J. STAGG (Syracuse): I think a point has been missed by both

Mr. Grossmann and Mr. Spalding. Attention has been paid to the differences in length and in length only. So far as I have seen in a cursory examination, there has been no attention paid to the differences in diameter by either Mr. Grossmann or Mr. Spalding, and I think perhaps some investigation along those two lines may reconcile the results of the two investigations.

A number of years ago I obtained a mass of data that was irrevelant until that point occurred but gradually after taking into consideration the changes in shape of both dimensions, results came to light which were worth while.

MR. GROSSMANN: I might say in reply to that, first that the series of measurements made by Mr. Scott in the paper referred to by Mr. Thum showed that the volume changes which were measurements of actual specific gravity, conformed rather closely to these results shown here.

The other answer that I might make to that has to do with a surface action. I don't know if Mr. Stagg has reference to the same point, but it is rather well known that if a cylinder of about the proportions shown here is heated repeatedly and then cooled quickly a certain surface action comes into play. ..... Now here, if a cylinder like this shown in Fig. Y is heated to a moderately high temperature, disregarding the critical changes, it is found after a number of quenchings, say 100 or 200, that the cylinder instead of having its regular shape, will be bowed out, like that, shown in Fig. Z, throughout the section which would indicate a contraction axially, in dimension M.

On the other hand, it is found that the cylinder, instead of being straight across as at S in Fig. Y, is actually bowed out here also, as in R in Fig. Z, and the same at the bottom. It seems that the tendency is for a piece of steel like that to assume a perfectly spherical shape; but that effect is not noticed to any great extent, at least, it was not noticed in some tests we made, until perhaps 50 to 75 quenchings had been made, and it seems to me very doubtful that such an effect would have much bearing on these measurements

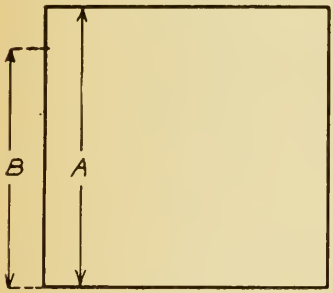

FIG. X

FIG. Y

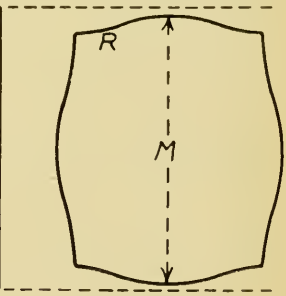

FIG. Z

Fig. X. Diagrammatic sketch of the change in dimension of a steel block when heated to 1800 degrees Fahr. and quenched in water.

Fig. Y. Diagrammatic sketch of a steel cylinder before it has been heated and quenched several hundred times.

Fig. Z. Diagrammatic sketch of the steel cylinder shown in Fig. Y after it has been heated through the critical range and quenched several hundred times. Note that the cylinder tends to assume a spherical shape.

because, in the first place these had only one quench, and in the second place, if there was a tendency toward contraction, which I grant there is, it would be slightly compensated for by the tendency to bow out at the upper and lower ends.

MR. KNERR (Philadelphia): In that connection I would like to ask whether you made measurements to determine whether the ends of the

cylinder remained parallel after quenching, or whether there was a bulging at the axis as compared to the length at the outside?

MR. GROSSMANN: Unfortunately we couldn't make those measurements because with this cylinder the ends were oxidized very badly 1/3 of the way in, and it was only in the center that the steel remained perfectly clean. So that we couldn't tell whether there was surface action there or not. I rather suspect that with the short heating it would be found that the outer part was expanded more than the central part. But I have no data on that.

MR. W. B. CROWE (Pittsburgh): I have had experiences in connection with the hardening of armor plate, that connects up very well with this subject. Armor plates which are face carbonized, are treated to produce the desired physical properties for the back, usually very uniform throughout the entire section. It is then subject to a face hardening operation, face heating, and face and back spraying, which will carry the hardening down to desired depth approximately 30 to 40 per cent.

It has always been our experience that when a plate has been so heated and quenched as to have no appreciable effect on the physical properties at the back, and the face has been rendered nearly glass hard, the upper hardened face will rise in the center very considerably. A plate 20 feet long will often rise 6 to 10 inches. To satisfy myself, in one case I placed two center punch marks 10 feet apart on longitudinal axes of surface, before heating for hardening. After hardening these punch marks were 1/16 inch farther apart and the calculated curvature this would produce checked very closely with the actual curvature induced.

I also observed that where in special cases a foot or so of the edges of the plate were protected to keep soft for subsequent sawing off, that when the cut had been carried nearly the entire length of the plate, the narrow, unhardened strip became nearly straight as compared with the hardened plate, the face end often leaving a foot or more above its original position. With these counteracting forces removed, the hardened body of the plate becoming slightly more curved. Inasmuch as the physical properties of the unhardened portion of the plate had been practically undisturbed, it would appear that the hardened face had expanded.

CHAIRMAN BOYLSTON: I would like to ask Mr. Grossmann what he means by two different types of martensite?

MR. GROSSMANN: There is pretty distinct evidence in high speed steels that there are two forms of martensite present; one of them the kind which is, let us say, "destroyed" by heating at the low temperatures up to 900 degrees Fahr., and the other which is only developed from the austenite in high speed steel by heating at 1100 degrees Fahr. I cannot say what the constitution of those two martensites is, but it is certain that martensite formed from the austenite at 1100 degrees Fahr. is much more stable than the martensite which is in the high speed steel as originally hardened. We can show this, for one thing, by heating high speed steel to 900 degrees Fahr. and it will lose some of its hardness. If it is then heated at 1100 degrees Fahr. it will acquire what is called secondary hardness due to martensite, and if this martensite, this new martensitic steel, is then reheated at 900 degrees Fahr., it retains the hardness which it had after heating the first time at 1100 degrees Fahr.; if it were the same kind of martensite as the original martensite, it would be destroyed at 900 degrees Fahr. the same as the original martensite. But this is not the case.

RELATION OF THE UNIVERSITY TO INDUSTRY

By Dr. J. G. Bowman

I am asked to talk about the relation of the University to industry, that is, the production of the University in its relation to industrial success, especially in the Pittsburgh district. I like to use your word here "production."

The budget of the University of Pittsburgh is about $1,500,000 a year. Our "production" this year will be about 600 graduates, about one-half of whom will go into the industries. The cost of training these young men and women during the past four years is conservatively about three million dollars. In other words, the community and the state of Pennsylvania contribute about three million dollars a year for the happiness, the prosperity, and the permanence of the state by investing in these youngsters.

Now, what about the product? Is it what you want? Is it all that we should have made out of it? You can employ today almost an unlimited number of engineers, technically trained, for $1,500 a year. You can employ doctors, dentists, and lawyers for the same amount, but can you employ a man trained in any one of these professions who knows not only the technical side of his profession, but knows also how to enter into the life of his community and be a part of it. A man in almost any profession today who has a sound training and also the gift of being part of his community is a bargain at $10,000 a year.

Now, what about our product. Are we turning out the $1,500 or the $10,000 man? Are we permitting a boy to leave the School of Engineering or the School of Medicine with merely a technical training, or have we some process by which a lad acquires both the technical training and that additional something which sets him free to go with speed to the top.

What is this "additional something"? There is no single answer to the question. The best answer, however, which I know is that it is the ability to get another man's point of view with sympathy and kindliness and speed. It seems clear to all of us in the University that it is our business to insist that the boys who are going into a professional career lay in for themselves a foundation which will broaden forever their points of view. Hundreds and hundreds of boys come to the University each fall and say, "I want to be an engineer. I want to be a doctor. I want to be a lawyer. I want to plan and build something." They are impatient. They want to go "right into technical training". The medical student, for example, wants to study anatomy and pathology before he has laid the basic foundation of medicine in chemistry and biology.

The engineering student is impatient when he is asked to acquire at least an elementary knowledge of economics and history and when it is insisted that he should know how to use his own language in a simple, straightforward manner which goes to the mark. If we should allow these boys to choose entirely their curricula, unguided as they are at the start, we should be turning out seldom better than $1,500 man and you,

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A speech delivered at the banquet of the Pittsburgh Sectional Meeting, May 25. The speaker, Dr. J. G. Bowman, is Chancellor of the University of Pittsburgh.

well, you would be complaining that you do not want many of these men.

What happens is that we require engineers, mining students, medical students and students in training for business to go at least two years to the College before they start on their technical training. In these years emphasis is placed upon training in the use of their own language. There is insistence that they know the elementary principles of economics and of government. The meaning of a profession is brought home to them and the responsibility of a man who enters a profession to his fellows. In other words, we try to open the windows on all sides of the little room in which the man starts out as a freshman, and with this scenery before him he is able not only to choose more wisely the career into which he will throw his life, but also to see more clearly the relation of his life to those about him.

The reading of biography is a habit which we endeavor to create among students. If a boy, for example, reads the life of Lincoln and really sees the horizon as Lincoln saw it, he will never again be quite as limited as he was before he read the book; he will have increased permanently the radius of his own horizon; he will have gained the power to grasp anothers' point of view with more sympathy, more kindliness and more speed because he knows the life of Lincoln.

The habit of using those little five and ten minute periods through the day that are wasted by most of us, for the reading of things like the life of Lincoln is a great habit. Many a time it is the difference between success and failure. It is a very important part of what a man gets out of a college education. And then if the student's life is full every minute of determinatnon to go to some high mark of attainment and he realizes that each day's work is progress straight toward that mark—that is the stuff which makes the University.

If you are to perpetuate your industries you must bring in constantly training and experience which you cannot give in your industries. Neither the engineer, nor the chemist, nor the doctor, nor the lawyer can acquire his essential skill without academic training, and the time is now here for co-operation between universities, let me say the University of Pittsburgh, and the industries of Pittsburgh, for the production of men who have got the energy, the intelligence, and the character to hold Pittsburgh in first place among world industries.

BALL STEEL

By Hilton G. Freeland

THE subject of this paper is ball steel from the ball manufacturer's view point. There are other phases to this subject, for example, that of the steel mills and of the bearing makers, but this paper deals with the ball manufacturers' problems arising from the quality of the ball steel received and its effects on the final product. The writer will show what is considered good ball steel by describing the types of defects which are most common and by explaining why they are so injurious to the quality of the ball makers' product. It will also be shown how certain operations tend to accentuate certain defects during production, also how their presence is discovered in the raw material as received.

At the plant with which the writer is connected the product consists chiefly of the most perfect type of balls which are to be used in standard, high grade, radial and thrust bearings that are required to meet the most exacting type of service. In addition to this balls produced for Brinell machines, valves, and for uses in which alloys such as stainless steel, Monel metal, brass, bronze, aluminum, etc., are to be preferred, but for the purpose of this paper we will confine ourselves to steel only.

At present, four different kinds of steel are in use which in order of their importance, based on output, are:

1. Regular ball steel for ball bearings
2. Steel for oil well valve balls
3. Steel for valve balls and bearing balls where resistance to corrosive action is of prime importance
4. Steel for Brinell balls

We will study only the first type, our regular ball steel for ball bearings.

This ball steel is electric furnace chrome carbon steel. The carbon range is between 0.95 per cent and 1.05 per cent, while the chromium content increases with the ball size. For ball sizes ranging between 1/8 inch and 5/8 inch inclusive, a 0.75 per cent to 1.05 per cent chromium is used; balls from 5/8 inch to 1 3/16 inch inclusive, have from 1.05 per cent to 1.35 per cent chromium content; above that 1.35 per cent to 1.65 per cent. The other elements are as follows:

	Per Cent
Manganese	0.30 to 0.45
Phosphorus under	0.025
Sulphur under	0.025
Silicon	0.20 to 0.35

It is extremely seldom that any dispute arises over the composition of the steel furnished. A laboratory comparison of different analyses has indicated that a variation in composition from that which is specified would not be advantageous. It has been stated that additional chromium is present in the compositions used for the larger sizes of balls. This is found necessary in order that the required hardness penetration may be procured so that the larger sizes of balls may support loads proportional to their size. Increasing the chromium content of the larger ball sizes simplifies the heat treatment by reducing the sensitivity of the metal to the effects of both heat and time.

A paper presented before the Detroit Chapter. The author, Hilton G. Freeland, is metallurgist, Hoover Steel Ball Co., Ann Arbor, Michigan.

The ball steel that we now use, owes its quality to the sincere co-operation of the steel mills with our laboratory and organization, and represents a tremendous expenditure of time and money; time in developing a mill practice which is capable of eliminating our main sources of trouble, and money required to defray the cost of these mill experiments and changes, also to cover losses incurred through rejected material. All mills which can successfully and consistently produce good ball steel have traveled the same path.

The chief types of steel defects which cause the greatest trouble in the production of steel balls are two in number, seams and decarbonization. The following are some of the reasons for this statement:

1. No metal is removed from the surface of the stock before forming; in addition we are limited through mechanical and production reasons from removing more than a certain amount of metal afterward.

2. The forming operations tend to accentuate certain defects in the material used.

3. The whole process of ball production after forming is fundamentally a grinding operation, and grinding is expensive.

4. The only way we can be absolutely positive that the finished product is free of the evil effects of seams and decarbonization is to procure raw material so nearly free from the defects mentioned that we know all traces of both have been removed before heat treatment of the balls. We will not dwell on methods of ball production except as necessary to show that the defects mentioned are serious, and the manner in which their evil effects become multiplied during production.

There are a number of ways of producing spheres both for the forming of ball blanks as well as for subsequent finishing operations. The following three methods of forming represent good ball making practice:

1. Cold pressing for sizes smaller than 11/16 inch.
2. Hot forming for sizes from 11/16 inch to 1¼ inch inclusive
3. Forging for larger sizes.

For the purpose of illustrating the accentuation which takes place in seamy stock through forming, we will consider cold pressing as generally typical, although considerably more drastic than either hot pressing or forging. Our practice is to make ⅝ inch balls and those smaller on Manville headers. In this process the wire used for making the ball blanks is fed from coils resting on spindles into the headers and then passes through guide rolls into a quill from which it emerges in front of the "cut-off" blade. A wire stop determines the slug length. The "cut-off," shears the slug from the wire and is so constructed as to carry it over between the dies and as the "cut-off" withdraws, the plunger die approaches the stationary die compressing the slug into the form of a ball blank.

One can readily see that if the wire were seamy, the seam in the slug would be greatly accentuated in the ball blank. An example of this condition is illustrated in Fig. 1 which shows steel ball slugs partly and completely formed into ball blanks. The accentuated seam is readily observed in both. The diameter of the ball blank is 50 per cent to 60 per cent greater than that of the wire from which it was made. This operation is repeated at the rate of from 80 to 135 times a minute depending on the size of the balls being formed. It must also be remembered that we are cold upsetting a steel containing 1.00 per cent carbon and 1.00 per cent chromium, possessing an average Brinell value ranging between 175 and 200. We have found

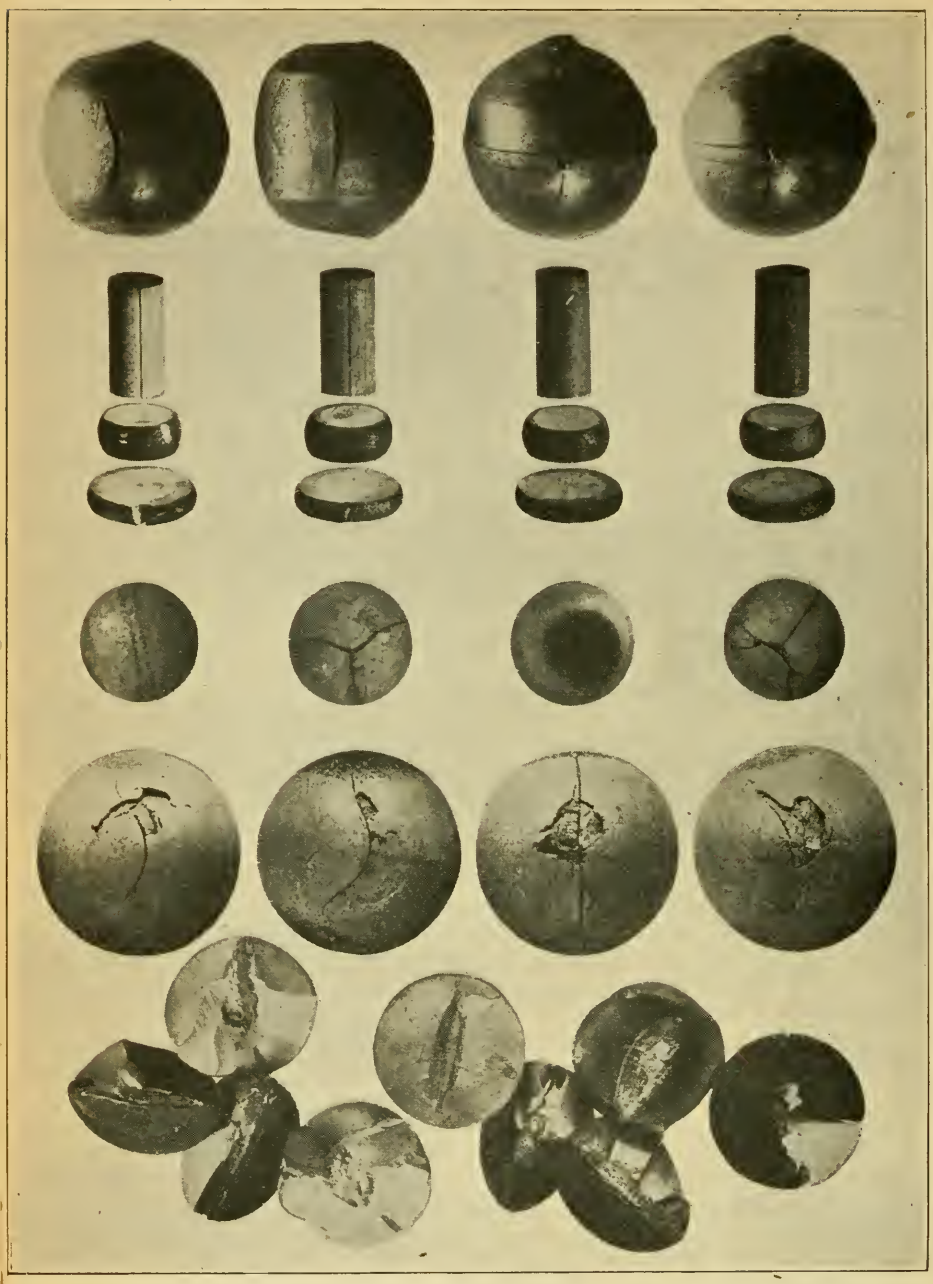

Fig. 1—The top row shows steel ball slugs partly and completely formed into ball blanks. The accentuated seam is readily observed in both. The second series shows two seamy slugs and two good slugs upset different amounts. The small balls across the middle of the figure are fire-cracked balls resulting from seams which were not completely removed before hardening. The large balls flaked in service due to unremoved seams. The pieces of broken balls at the bottom of the figure show a piped condition. Slag inclusions are noticeable.

that the accentuation of seams by this process varies greatly ranging anywhere from 1 to 5 times. Fig. 1 shows two seamy slugs and illustrates the manner in which seams are enlarged when the slugs are upset different amounts. With sound steel free from seams this crack would not occur.

In addition to the accentuation which occurs to seams we have also another factor to reckon with and that is the offset of the dies. Fig. 2 illustrates diagramatically this off-setting. Of course, this condition can be controlled within narrow limits but the dies in a header operating rapidly on this type of ball steel cannot be kept perfectly in line so we have to figure for a minimum ball blank diameter which occurs close to the portion of the ball we term the equator and is indicated as *B* on the diagram. The equator is the section of the ball where the flash is formed during cold pressing. The maximum cold working stress as well as the greatest accentuation occur at the equator, therefore we have the greatest defect in the headed ball at the point of least diameter. Thus a slight offset may cause the loss of balls that would otherwise clean up before hardening. In removing a defect it is necessary to grind off an amount of metal equal to at least twice its depth. This off-set of the dies is one of the factors which determines the permissible limit of decarbonization in the original stock of which the balls are made.

The next point for consideration is the manner in which seams become deepened during ball manufacture as well as the effects of decarbonization in the raw stock. After the ball blanks are formed they receive a rough grinding which removes the flash and most of the excess stock, they are then hardened. The balls produced from wire are given one heat treatment which is accomplished through a continuous process in rotary furnaces. At this stage of manufacture it is necessary that all seams and decarbonized metal be entirely removed, if not, the seams become accentuated again, frequently but not always producing fire-cracked balls. The situation would become much easier of solution if all the balls which possess remnants of seams at this stage would fire-crack, because they could easily be picked out after hardening, at some subsequent operation, or finally by the inspection department. We would then know that no future trouble would be experienced by exfoliation or by the breaking of balls in service. Fig. 1 shows several small balls which have been fire-cracked.

Tests for seams are made by cutting samples from enough coils to give a representative idea of the quality of each shipment. The test pieces are etched in dilute muriatic acid, either 1 to 1 or 1 to 3 parts of water, then rinsed in running water to free them from acid, and afterward cleaned with one of the ordinary kitchen cleaning compounds to remove any residue which may adhere to the samples. The test pieces are then dried and are ready for examination. This examination is performed by filing any seams that may be present until the bottom of the seam is reached. The depth is determined by use of a micrometer. The most accurate results are obtained by holding the samples in a vise, inasmuch as some of the seams are very fine and can easily be lost unless the filing is done in the most careful manner. These details of testing may seem most simple and yet nearly all of our disputes with the steel mills arise from a lack of strict adherence to the details of the operations just described. There are three types of seams which appear most often and are mentioned here without any attempt being made to explain their causes. All are equally serious to the ball maker.

Type 1. Are long seams of greater or less depth usually continuous

throughout the length of the section and occurring singly or in pairs and usually having complementary seams diametrically opposite. The two seams comprising each pair are parallel throughout their length but converge as they approach the center of the wire or rod. Fig. 3 in the upper left quarter shows a piece of bar stock which has seams characteristic of Type 1 and has been file tested as described.

Type 2. Are seams which may vary greatly in length or depth and also in their location on the bar. They may occur singly or a large number.

Type 3. Are seams which are always short, some of them not over ½ inch in length and of varying depth. These are found on both rod and wire but appear to be most serious on bar stock where they are found to be from 0.015 to 0.025 inch in depth or even greater.

No final inspection has been developed which is so perfect that it can be absolutely known that seams do not actually exist in the balls received by the customers when stock is used for their production which contains seams deeper than a certain limit. This is the reason that material used for ball

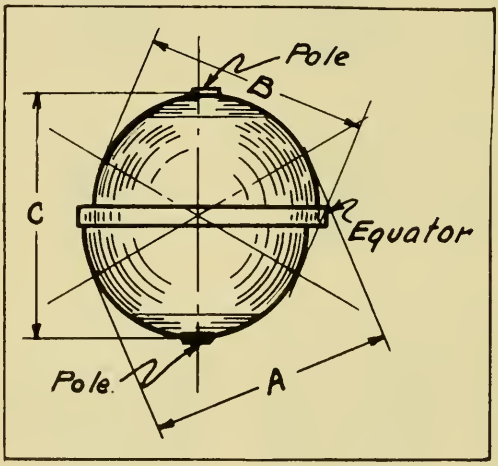

Fig. 2—Illustrating the off-set of dies resulting in a ball having a maximum and minimum diameter.

production is under such rigid restrictions against seams and the reason that it is rejected without allowance when the limits are exceeded. The specification states that no seams or surface defects of similar type should be present, but commercially, this is not possible of complete fulfillment. Our production methods indicate that 0.007 of an inch on radius is the maximum limit, while stock accepted usually possesses seams not exceeding half that limit, and in many cases ranging from zero to 0.002 inch only. Fig. 1 shows some balls that flaked in service. It will be noted that the flaking started from an unremoved seam in each case.

Let us now consider decarbonization limits. We require that at a distance of 0.004 inch below the surface, the stock must contain its full quota of carbon. In the lower right hand corner of Fig. 3 is shown three etched pieces of decarbonized wire. The plain gray wire *A* has the normal appearance of good stock while *B* and *C* are finely and coarsely mottled, respectively. This mottled condition generally indicates the presence of decarbonization. Wire like *C* usually has more decarbonization than stock

having the appearance of *B*. The lack of this peculiar surface condition, however, does not indicate that the material possesses its full quota of carbon as required. Where the decarbonization is quite bad it often manifests itself by a sparkling ring on the outer edges of the hardened test-pieces as is shown in the lower left hand corner of Fig. 3.

Balls will contain one or more soft areas, when made from wire possessing decarbonization to such a depth that it is not entirely removed from the minimum ball diameter before heat treatment. This depth of softness would be greater than the depth of decarbonization not removed, owing to the blanketing effect of the carbonless metal on the surface. Experience has shown that decarbonization on the surface of a ball, on account of this blanketing effect, produces, in some cases, a depth of softness at least several times greater than the actual depth of decarbonization present at this stage. This has been proven during production where soft spots were found in a given lot of balls.

For example, the depth of softness when discovered might range between 0.003 and 0.004 inch. At this stage of manufacture it would not be possible to remove much more of the excess stock before hardening and have the balls finish up correctly to size. In this event, hardening would be temporarily suspended on the lot in question while the balance of the unhardened balls would be sent back to the grinding room and 0.001 to 0.002 inch more would be removed. On being returned to the heat treating department and hardened it is usually found that all traces of surface softness have entirely disappeared although less stock than the depth of apparent softness has been removed and no changes in heat treatment have been made. It might be asked by some how we know that the balls which received the additional grinding originally contained decarbonized areas. The answer is that our experience shows that after a number of tests on the first portion of quantities of balls consisting of a ton or more, that they have agreed consistently, as to the precentage of soft balls after heat treatment.

There are two things of interest that might be mentioned here, and they also explain the reason we are compelled to inspect most rigidly and to reject on the limits given without any allowance.

1. When either seams or decarbonization are present they are not of uniform depth throughout the length of the coil or rod nor are they necessarily continuous.

2. That decarbonization when present will appear in two forms. In one type the surface metal will be composed almost entirely of ferrite possessing a more or less sharp line of demarcation at its junction with the metal having at least our minimum carbon allowance. The upper left hand photomicrograph in Fig. 4 shows the first type of decarbonization where the surface of the stock is almost entirely free of carbon. The stock is 0.365 inch wire as received in the annealed condition. The magnification is 75X, and the specimen was etched 40 seconds in a 3 per cent solution of nitric acid in ethyl alcohol. This type is easy to identify either by the microscope or the file test after hardening. The photomicrograph shown in the upper right hand portion of Fig. 4 shows a cross-section of 0.145 inch ball wire in the annealed condition as received. The mode of preparation of the micro-section and the original magnification are the same as for the previous picture. The carbon content of the metal contained in the first 0.004 inch taken off the radius was 0.51 per cent. This photograph illustrates the difference between the two types when viewed under the microscope.

A number of sections were examined under the microscope at higher magnification but it was difficult to identify the defective materials with any degree of certainty. This second type is more serious and is termed

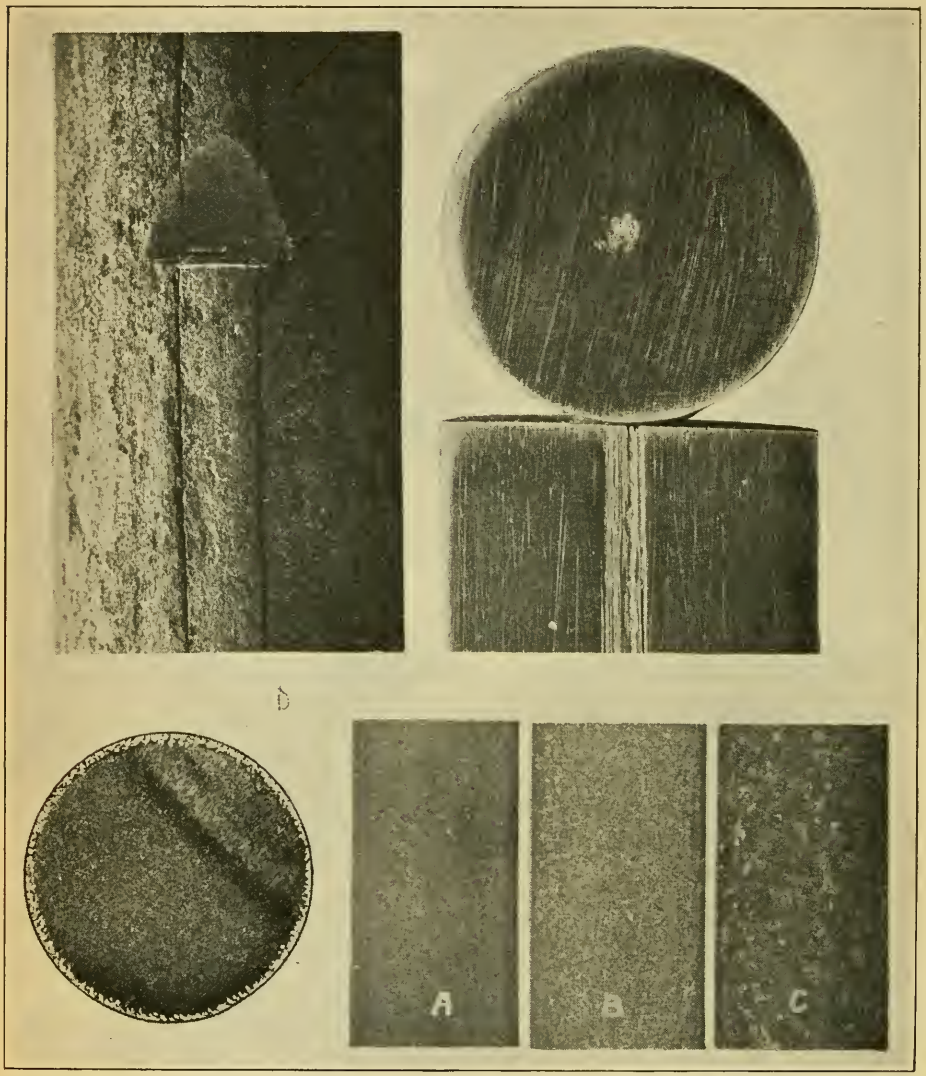

Fig. 3—In the upper left hand quarter is shown a piece of bar stock which has seams characteristic of Type 1. In the upper right hand quarter is shown two macro sections of a piped bar. The lower left hand photograph shows the sparkling outer ring on the edges of a hardened bar. This condition is due to decarbonization. In the lower right hand quarter is shown three etched pieces of decarbonized wire. Wire A has the normal appearance of good stock while B and C are finely and coarsely mottled. This mottled condition generally indicates the presence of decarbonization.

"graded decarbonization." All decarbonization is more or less graded but in this type it is accentuated. The surface of the metal may contain perhaps 0.50 per cent carbon, 0.004 inch farther in 0.60 per cent, 0.004 inch more may reveal 0.70 per cent carbon. and so on. Tables I and II

show the manner in which the carbon content increases as the center of the stock is approached, also that the quantity of carbon at any given depth varies greatly in different coils. This type also varies throughout the length of the coil both as to depth and continuity. It is very difficult to detect with certainty either under a microscope or with the file test after hardening. It has been found in hardening this type that the number of defective balls, that is balls showing one or more soft areas after heat treatment, may be decreased by the following methods:

1. Hardening additional times
2. By raising the temperature from which the balls are quenched
3. Quenching in water, if the balls are of a size which is usually quenched in oil
4. By tumbling after the first heat treatment in order that the scale formed thereby will be removed, and then giving the balls an additional hardening. All of these practices may tend to reduce the loss sustained by use of this type of metal, but it will be found that the only way to produce balls which possess uniformly hard surfaces is to reject this type of material when found, without making any attempt to use the stock by changing shop practice. The positive proof of the presence of this second type of decarbonization is by analyzing the different layers for carbon, but this represents a long job and is slow and difficult in cases where wires of small cross-section are tested.

The distribution of the decarbonized areas sometimes causes a great deal of difficulty when attempting to detect the presence of decarbonization in a given lot of wire. This condition is more serious when the decarbonized sections are of small size, often less than ½ inch in length and appearing on one side of the wire only, not necessarily around the section. These spots will appear at irregular intervals throughout the coil length but not necessarily on the same side of the wire. In the regular test for decarbonization we heat treat small sections of the wire without removing any of the surface metal, but when in doubt we remove the first 0.004 inches on radius from the wire being examined. In cases of the type in question we have found that small sections which would not harden correctly would be present even after the removal of the surface metal, before hardening, to a depth equivalent to our maximum permissible limit for decarbonization. Owing to the fact that these areas are so small it would be almost impossible to prove the existence of decarbonization by removing metal from the sections in question and analyzing them for carbon.

It can be deduced from the previous remarks that the microscopic examination of chrome carbon ball stock for the presence of decarbonization is not a reliable laboratory method for the protection of the customer against this type of defect. Decarbonization is tested in our laboratory by heating small samples of the wire in an electric furnace and quenching them in oil or water from a temperature which is a little higher than that actually required to produce the grain structure we desire in our finished product. This practice tends to eliminate disputes arising from the question of underheat, in cases where the presence of decarbonization is questioned. The test pieces are quenched from a metal tray in sets so as to produce uniformity and prevent any chilling effect of the tongs. The tray is supported above the bottom of the furnace to insure against any lack of uniformity in heating. The samples are quenched from a slow rising temperature while the heat treatment is recorded on a recordering pyrometer. Wire smaller

than 0.235 inches is quenched in oil which is at room temperature, while stock of larger section is quenched in water. At one time we had a dispute with a mill over a shipment of steel which we claimed would not harden satisfactorily. The mill contended that the temperature of the oil should range between 100 degrees and 140 degrees Fahr. as the increased con-

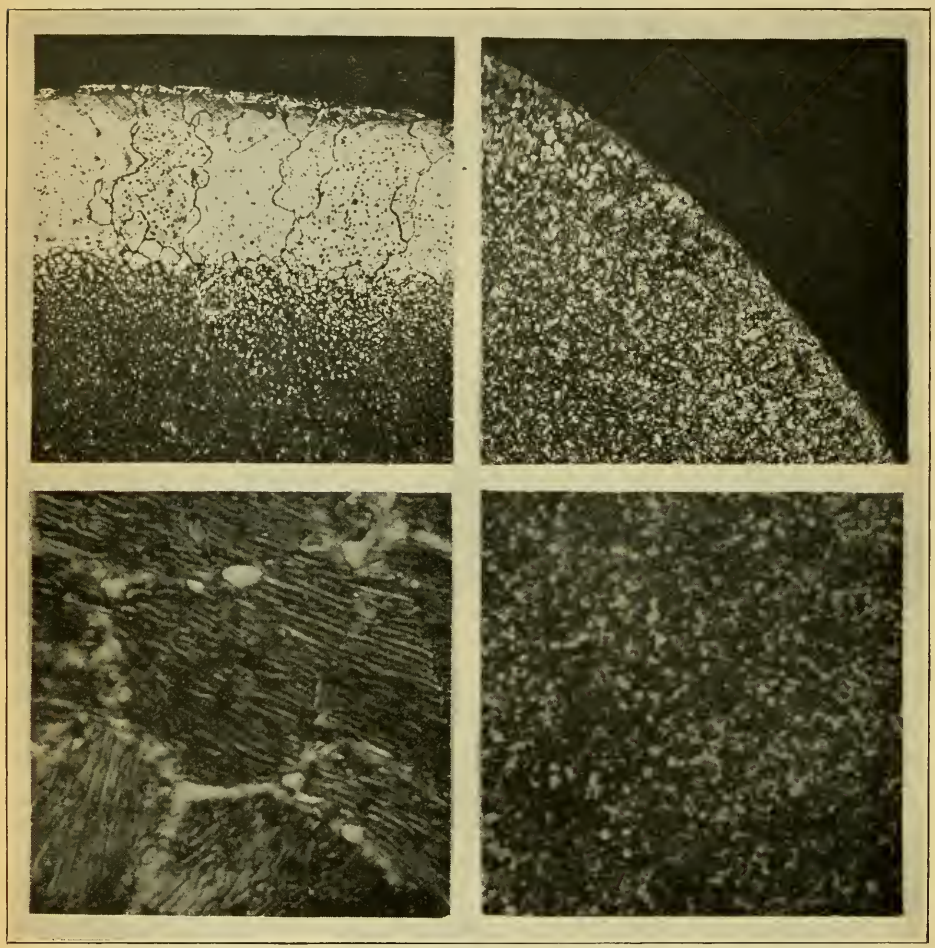

Fig. 4—The upper left hand photomicrograph taken at X 75 shows the first type of decarbonization where the surface of the stock is almost entirely free from carbon. In the upper right hand photomicrograph taken at X 75 is shown the second type of decarbonization known as graded decarbonization. In the lower left hand photomicrograph taken at X 1000 is shown a large grain structure bounded by carbides and accompanied with pearlite. This condition is due to faulty mill practice. In the lower right hand photomicrograph taken at X 1000 is shown the spheroidized structure which is preferred, having well dissolved and distributed carbides.

ductivity of the oil at that temperature would produce more effective hardening. One set of samples of the stock in question was quenched in oil at room temperature (approximately 75 degrees Fahr.) while the other set was quenched in oil at 120 degrees Fahr. If any improvement was present in the test pieces quenched in the hot oil it was not very marked, and certainly was not capable of convincing us that it was necessary to use heated

oil when hardening good ball steel. If the difference in temperature, of the range cited, would produce a marked effect in the hardness of ball stock, we would experience trouble more often in our regular hardening room practice on starting a furnace when the oil in the tank had dropped to room temperature than after the same furnace had run for a number of hours. This condition would become apparent to us when you consider that the balls are examined for what we term superficial softness, which means that the amount of softness when present will allow the operator to scratch the surface of a ball with a new file, but will not permit him to cut a small flat upon the ball. Considering the ideal shape of the surface of the ball for file attack, and the leverage which may be secured by use of a 10-inch file, you will perceive that the test is most severe from a hardness

Table I

Graded Decarbonization

Cut No.	Carbon Content per cent	Amount of Metal Removed from Radius
1	0.63	0.004 inches
2	0.67	0.004 inches
3	0.79	0.005 inches

Table II

Graded Decarbonization

Cut No.	Carbon content per cent	Amount of Metal Removed from Radius
1	0.47	0.004 inches
2	0.67	0.004 inches
3	0.83	0.005 inches
4	0.93	0.005 inches
5	0.99	0.006 inches

Cross section of wire as received contained 0.94 per cent carbon

Cross section of wire after 5 cuts contained 0.97 per cent carbon

standpoint. In all of the tests that we use we endeavor to have them approach as near as possible actual working conditions.

In the production, 5/16 inch balls, which correspond to 0.235 inch wire, also balls of smaller diameter down to ⅛ inch, they are quenched in oil. Sizes smaller than ⅛ inch are water quenched as are also those larger than 5/16 inches. We use only running city water in our water quenching operation. This applies to spheres 2 inches in diameter and larger. It might be mentioned here that our 2-inch balls are hardened almost to the center by this type of quenching.

In hardening from a rotary furnace, the balls are fed into a screened hopper which in revolving removes any steel dust or loose dirt that may be present, while at every revolution an adjustable bucket supplies the retort with a definite quantity of balls. The retort is made of a heat resisting alloy and has a spiral in its interior which causes the balls to travel to the discharge and where they slide down a short chute into the quenching bath. On entering the bath they are caught by a metal spiral which is enclosed with a heavy wire screen. They pass down this spiral to the bottom of the tank and are discharged into a wire basket 14 feet below the

surface. It is essential that the balls should not drop any great distance and collide with either themselves, the chute, or the quenching spiral, as at this stage some sizes have only from 0.003 inches to 0.004 inches excess stock, and the metal being more plastic while hot would flatten under the impact to such an extent that these flat areas would not be entirely removed in the finishing operations and would thus render the balls useless. The water used in the quenching bath flows outward from a tube in the center of the spiral; this tube having holes at several levels near the top supplies the coldest water where it is most needed. The behavior of the furnaces is indicated by recording pyrometers while a signal system consisting of a bank of lights informs the operators of their furnace conditions. The temperature is recorded from two points in the larger furnaces and is plotted as one curve by a two-point recorder. One point of each of the smaller furnaces is recorded and the position of the point is located slightly forward of the discharge opening. Gas is used for fuel and very little of the products of combustion enter the retorts.

Another very serious defect in ball steel are pipes. They prove very difficult for the ball manufacturer to guard against. In the upper right hand quarter of Fig. 3 is shown two macro-sections of a piped bar, one is a transverse section while the other is longitudinal, both from the same test piece. The piped condition is plainly visible in the center of each section. As a protection against this defect we break and examine the hardened sections of wire which were used for the decarbonization test. In the case of bars we grind the sawed ends of the samples and examine these. One coil or bar containing a pipe, is considered as sufficient cause for rejection of the shipment. This seems drastic, but when piped stock is formed into balls, unless the balls break in hardening as they often do, the subsequent grinding laps the metal over the pipes. The pipes then become very difficult to detect by our inspection department, especially on the smaller sizes of balls. At the bottom of Fig. 1 is shown pieces of broken balls which were piped. The included slag is readily discernible in several of the pieces. It will be noted that the piped areas are smaller at the ends than at the center and that the surface metal has been rolled over the ends of the pipes thus obscuring them.

In the case of wire it is necessary to specify Brinell hardness limits. These are 175 to 200 using a 1000 kilogram pressure and a 5 millimeter ball on account of the small cross section of the stock. The Brinell impressions are taken on the center of the transverse section and not on the outside. Cold upsetting a 1.00 per cent carbon, 1.00 per cent chromium steel at the rate of 100 per minute as a single stroke operation, is hard on dies, hence the upper limit. A lower limit is required because metal which is too soft tends to stick in the dies and does not shear satisfactorily. In shearing steel that is too soft the slug tends to bend a little too much just before the shear has completed its work. This causes a small piece of metal to remain protruding from the end of the slug and during the forming operation this is pressed into the ball. On subsequent grinding the lapped metal drops out leaving a cavity which is not removed during the finishing operation. In addition to this the slug tends to pass into the cavities at an angle which produces other complications, often resulting in damage to the machine.

The following points regarding size tolerance of raw material will be of interest. Wire up to and including 0.440 inches is ordered cold drawn to plus or minus 0.002 inches of a given size, and is supplied annealed to

meet our Brinell requirements. Rod for hot pressing is cold drawn to plus or minus 0.004 inches and is not annealed after cold drawing as this stock is hot sheared and hot formed. Rod for forging is given a tolerance which varies with the size of the stock, for example, bars under 1¼ inches in diameter are ordered minus 0 and within plus 0.012 inches. The diameter of the stock is considered as the mean of the largest and smallest diameters of the bar. In the case of wire and rod for cold and hot pressing, we find that when the stock has as little play within the quill as possible, we get the best results in shearing. Rods which are used for hot pressing require more play than wire which is fed automatically in the cold pressing operation. This is rendered necessary by the variations in expansion of the bars at different temperatures also on account of the stock being hand fed.

It is this relationship between quill clearance and correct shearing conditions that accounts for the close tolerance required in stock sizes used for cold and hot upsetting. On account of it being necessary to have this greater clearance in the quill used for hot pressing, we have increased slightly the tolerance of stock for hot pressing over that used for cold forming, thus reducing the cost of the raw material. Our experience has indicated that hand feeding stock when hot pressing is more advantageous than using the complicated apparatus which is necessary to correctly heat the rod, feed it into the machine, shear it, and form it into a satisfactory ball blank. Also, in the case of imperfect shearing or other accident, the stock can be more readily withdrawn avoiding damage to the machine. The machine that is used for hot pressing, forms at the rate of from 60 to 70 blanks per minute. In forging, a definite amount of stock is required to fill out the ball blanks. This explains the need for a zero minus tolerance, while stock carrying too great an excess on diameter produces an overfilled ball and the removal of this extra metal increases the cost of the resultant product. Stock for forging is supplied in multiple lengths which reduces loss through short ends. Rust or lead adhering to the surface of wire used for cold pressing is very objectionable as it gradually collects in the dies during the forming operation, producing a binding action on the newly formed ball blanks, thus retarding their discharge by the knockout pins. When this occurs another slug is fed over to the dies before the ball escapes and a "double-header," as it is called, is formed. This double-header often breaks the "cut-off" and frequently does other damage.

Occasionally we have trouble where the grain structure of the metal as received is too coarse. The ball manufacturer cannot afford to correct this condition, nor would it be wise for him to attempt it, even if it could be corrected, therefore we reject this type of material. This coarse grain structure is usually discovered in our laboratory tests at the time the stock is received. The appearance of the fractured ends of the heat treated sections used for the decarbonization test usually gives us a clue to the presence of this type of defect which is later confirmed by laboratory examination. With one exception this fault has appeared in wire sizes only. Balls made from this class of metal would not support their required minimum load at the heat treating stage, while the fractures would be coarse grained and dead. This condition is very rare and is usually accompanied by excessive decarbonization. The lower left hand quarter of Fig. 4 shows a photomicrograph of 0.365 inch ball wire. The large grain structure bounded by carbides also the accompanying pearlite is clearly defined. This steel apparently had been subjected to a very high temperature at the

mill, followed by very slow cooling. The magnification of this transverse section is 1000X. The steel is as received. The photomicrograph in the lower right hand quarter of Fig. 4 shows a transverse section of 0.320 inch wire, as received. The magnification is 1000X, the same as the previous picture. This is the spheroidized structure which we prefer, having well dissolved and distributed carbides.

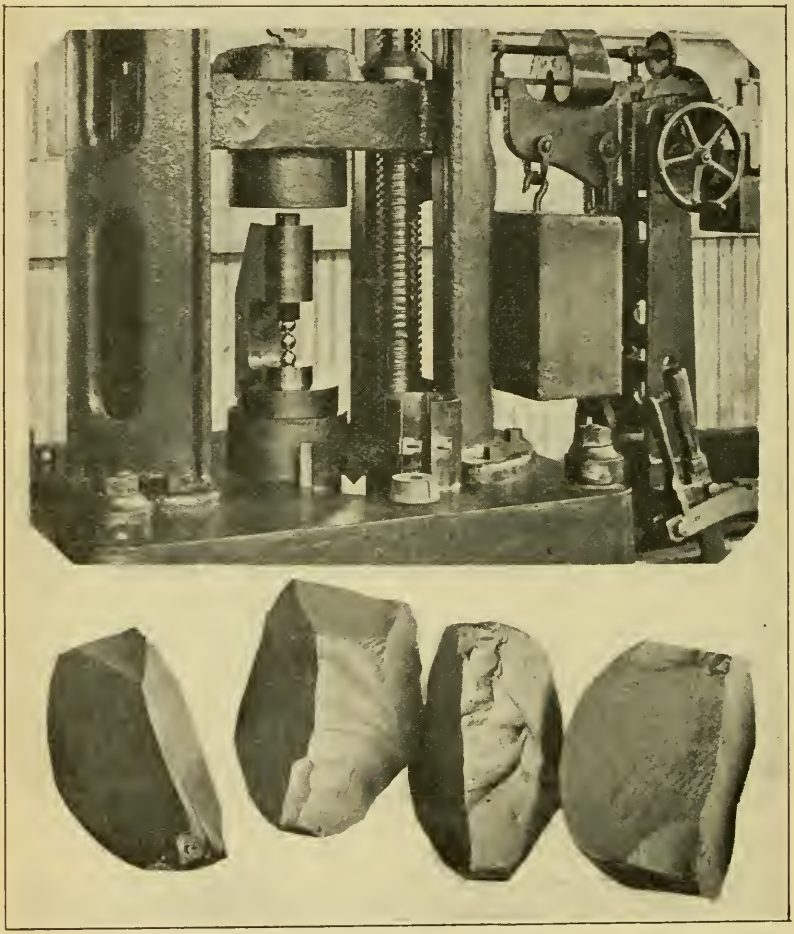

Fig. 5—Showing the jig used in the testing of balls when determining their crushing strength. Three balls are superimposed between a plunger and a supporting anvil. The pressure is applied by means of a universal testing machine. A number of fractured balls are shown below. The rugged appearance of the fractures and the fine, uniform grain structure are clearly defined.

Fig. 5 shows the jig used in the testing of balls when determining their crushing strength. The three balls are superimposed between a plunger and a supporting anvil. The pressure is applied through the plunger by a universal testing machine. Small V blocks are used to align the balls, while a guard placed around them protects the operator during the test. A number of fractured balls are shown below the testing machine. The rugged

appearance of the fractures and the fine, uniform grain structure are clearly defined.

In hardening balls we aim to produce a surface which will resist being attacked by a file, and at the same time, we endeavor to preserve the elastic properties of the metal so that the balls will render satisfactory service in bearings and not fail under varying stresses. No doubt, resistance to fatigue is also insured, to some extent, by the uniform surface hardness and its necessary accompanying uniformity of structure throughout the ball. In addition, the high degree of surface finish possessed by the balls probably aids materially, as well as the immersion in boiling water after hardening. This treatment in hot water has an ageing effect by providing an opportunity for the release of internal stresses. The fact that we have extremely few complaints where our best grade of balls are subjected to the most exacting conditions of service, appears to verify these conclusions. In case of question, we can identify the troostitic areas on the finished balls where very small sections of softness occur. Sometimes these small sections are no larger than the head of an ordinary pin.

The Brinell hardness value of the finished balls is in the neighborhood of 650, this value being determined by the use of a 10 millimeter ball under a 3000 kilogram pressure. The Brinell impression is made on a small flat of convenient size which has been ground on the hardened surface of the finished ball. The scleroscope hardness values vary with the mass and other factors, therefore it is necessary to refer to a plotted curve in order to determine the correct value for a given size of steel ball. Sometimes we meet with hard sections in the wire coils. They are difficult to find in the laboratory examination of the shipment and are probably due to some fault at the mill which produces a lack of uniformity in the annealing operation. A great deal of trouble is experienced when coiled wire contains hard spots. Quite often these extremely hard sections fail to shear correctly and sometimes they do not shear at all but simply break off in a very irregular manner. When wire breaks, instead of shearing, the lack of uniformity of the operation will cause the slug to be carried over between the dies at such an angle that serious damage is done during compression. A slug made from wire which breaks will not make a good ball because cavities will usually be present at the poles of the finished ball owing to the irregularity of break at the original slug ends.

In conclusion the writer desires to say that he realizes that a great deal more can be said regarding the requirements of good ball steel, but has only attempted to cover at this time, in more or less detail, the problems which most frequently confront the ball manufacturer when purchasing steel for the manufacture of a product which is expected to fulfill the most exacting requirements during service.

Discussion of Mr. Freeland's Paper

MR. DANSE I want to compliment the speaker on his clarity of speech. I do not think we could have gotten anybody to explain this or any other problem in better English or in a better manner. I want to thank Mr. Freeland on behalf of the Society. It is a very interesting subject to all of us, I am sure. Are there any questions you would like to ask him regarding this subject? He came very near telling it all but maybe he has not. One thing I would like to ask him is regarding service of balls for Brinell ma-

chines. Is it possible to insure service of 10 millimeter steel balls in Brinell service on hard parts which run in the neighborhood of 500 to 520?

MR. FREELAND That is a proposition we have been working on for some time. We have endeavored to procure a steel which would be satisfactory when testing hard materials where the hardness values range anywhere between 500 to 700, or a little more. The difficulty is in procuring a type of stock which when hardened will possess enough excess hardness over the material under test. We are using at the present time a steel containing tungsten with a high percentage of carbon. During the war, Government inspectors at our plant claimed that the Brinell balls made from this steel would give a service of 200 tests as against the regular chromium steel ball which had previously been supplied and which they rejected after being used for about 40 determinations. Of course, the great difficulty to be overcome is the deformation which takes place in the Brinell ball and this is variable. We have no way of controlling this except by procuring a type of stock which will become extremely hard when correctly heat treated. In fact, we sacrifice somewhat a fine grain structure and incidentally some of the resistance of the balls to shock in our endeavor to produce a superhardness. This special Brinell ball is about 50 points harder than the regular chromium steel ball of the same size and is certainly a great deal tougher. I realize this is a very important problem. If anyone in the audience has any suggestions to give with reference to a steel that will be superior to the one we are using the speaker would be glad to hear from him.

UNANNOUNCED SPEAKER In the last paragraph I believe you said that the difficulty of the broken end was what spoiled the ball rather than the brittleness of the material.

MR. FREELAND I was considering the matter from an inspection standpoint. Supposing that the ball would otherwise be alright, it is defective from the beginning by the fact that there are cavities at the ends of the ball owing to the irregularity of break. This would cause its rejection by the inspection department. Sometimes the wire is brittle but will still shear. If this brittleness was caused by a slight irregularity of mill anneal or in drawing and the grain structure is not too coarse the subsequent heat treatment which it receives at our plant would correct it. Usually the hard spots are not long and most usually appear on one side of a coil.

UNANNOUNCED SPEAKER Would that also apply to the irregularities you found in decarbonization?

MR. FREELAND I think so. Of course, I am not at the mill, and in talking about a plant at which you are not located you do not know the fine details. The manner in which the decarbonization is distributed and from its irregularity of occurence in a given shipment I would say that it may be caused in some cases by overheating the stock for rolling or in the normalizing and annealing operation of the rods before cold drawing. It seems to me that when the graded condition occurs a small amount of carbon is first removed and later more carbon is removed from the surface with an accompanying diffusion of carbon from the section of higher carbon content toward the surface. The result is thus cumulative and over a period and varies greatly. One coil may contain the required carbon content, say within 0.008 inch of the surface and the next test piece of presumably the same heat treatment and anneal will require the re-

moval of 0.020 or 0.030 inch before sufficient carbon is reached.

MR. WEBSTER Why is water quenching used for the two extremes and oil for the medium size?

MR. FREELAND In the case of balls which include sizes from 5/16 inch down to 1/8 inch we find the oil quench most satisfactory because we obtain the necessary hardness and other required properties without resorting to a water quench which is more drastic, while with the smaller balls we are unable to obtain a uniform quench in oil because of the lack of uniformity in the loss of heat which occurs in these extremely small masses of metal during the transference of the balls from the heating element to the quenching medium. This is not done automatically as is the case with larger sizes but the balls are heated in nickel-chromium tubes submerged in a lead bath and are then transferred to the quenching medium by inverting the tubes. Water being more drastic than oil as a quenching medium compensates for the loss of heat referred to. The larger sizes we quench in water to obtain the necessary penetration of hardness and this with the increased chromium content used in larger ball sizes produces spheres of uniformly high load carrying capacity and endurance. We attempt to quench steel of the right chromium content in such a manner as to produce a ball of the required strength and surface hardness without unnecessary sacrifice of the elastic properties.

MR. WEBSTER I was wondering if the small balls did not show more defects.

MR. FREELAND The small balls show less defects mainly because the drawing at the mill tends to eliminate both decarbonization and seams by reducing their depth. As an illustration, a short time ago we rejected a shipment of 0.365-inch ball wire on account of the presence of a small amount of decarbonization. The mill in question asked if we would be willing to have them take the material back and reduce it to 0.320 inch or a size smaller in order to reduce the depth of decarbonization to an amount within our permissible limit. We agreed that this would be satisfactory but the defect would have to be eliminated. We have less loss through fire-cracked and part soft balls on small stock than on large for that reason.

MR. DANSE Would you mind telling us something of the class of steels used for header dies?

MR. FREELAND The die steel proposition is a serious affair with us because it affects the rate of production and on account of die cost. We have tried nearly all steels including a number of freak steels and found straight carbon steel ranging from 1.00 per cent to 1.10 per cent far superior to any of the alloys including vanadium, chrome vanadium and others of those alloys which you might think would be satisfactory. We have found crucible die steel which has been hammered in two directions and rolled to a round of required size superior to the same type of steel where the stock has been upset. We could probably use a little lower carbon, perhaps 0.90 per cent to 0.95 per cent except for the fact that our die cavities are small, thus rendering it very difficult to get the depth of penetration required at the bottom of the cavity. Many steels that appear to have worked for other people have not stood up for us.

With reference to shearing blades, I might say that we use a steel con-

taining between 12 per cent and 14 per cent chromium, heat treated by quenching in oil from a temperature from 1650 degrees Fahr. to 1700 degrees Fahr. I thought at one time that this temperature was a little excessive so we tried about 100 degrees lower but it did not make any marked difference. We get excellent results at that temperature, therefore, we did not make any change.

MR. WEBSTER May I ask if there is a marked difference between the cold pressed as compared to hot pressed balls?

MR. FREELAND I can answer a part of your question and a part I cannot answer. The weakest line of a ball is along the line of original rolling of the stock. When we upset the ball we tend to destroy that structure somewhat, but nevertheless, when the plane of applied pressure is across the end grain of the stock and not in a line with it the ball supports the greatest load. There is not a great deal of difference but there is some. I do not believe there is a marked difference between hot pressed balls and those which have been cold formed. If the subsequent heat treatment would remove the effect of original working at the mills we would not expect to find any difference in the balls whether compressed through the equator or in a line with the poles. In hot forming the stock is heated up to about 1800 degrees Fahr. and then worked. If the heat treatment the cold headed balls receive does not remove the effect of original rolling even after the steel has been upset into the form of a ball blank it is not likely that the hot pressing operation would produce a different result. There is one marked advantage in hot pressing over forging and that is that the metal in hot forming is not heated to the high temperature which is usually used in forging and the finishing temperature is much closer to the critical point of the steel. The internal strains arising from cold pressing are greater than those from hot pressing but in both cases these are relieved by the subsequent heat treatment, while after being quenched, the balls are immersed in boiling water for at least one hour and this tends to relieve the hardening strains without affecting the surface hardness of the balls. The crushing pressures of our cold and hot formed balls conform to the same formula.

UNANNOUNCED SPEAKER I would like to ask Mr. Freeland how he quenches the dies, especially the surface where the heading is done, where the enormous pressure comes in the process of forming.

MR. FREELAND If we had a blackboard I could show you. The quenching jig is shaped somewhat like a cup with water coming up through the center while the die rests in this cup supported by a small ledge of metal, most of the die face being exposed to the action of the quenching medium. At the bottom edge of this cup are holes for the escape of the excess water while the pressure used is sufficient to drive the water through the cavity and up through the knock-out pin hole thus eliminating any possibility of a gas pocket. The cold water runs continuously. It will be seen that the preferential quench is at the cavity. This is the most successful method that we have found. We have tried quenching by complete immersion in water but in this case the cavities were not hard enough.

We at one time prepared a jig by means of which the dies could be completely immersed in running water while a preferential quench was given to the cavity itself but this was not satisfactory. The dies appeared to be too hard and would chip or break. The jig was constructed of four rods joined by a circular section of metal at the top and bottom. The rods

were equally spaced and were far enough apart to accommodate the die being quenched and were about 30 inches long. This jig was immersed in a tank of running water while a pipe which conveyed a stream of water under high pressure was projected into and centered in the bottom of this jig. In order to quench the dies it was only necessary to invert them and place them in the jig down which they would pass until they came in contact with the pipe at the bottom. By this means a stream of water would be forced through the die cavity and knock-out pin hole, while the balance of the die would receive a complete quench owing to its immersion.

With further reference to the composition and type of die steel used in heading I would like to say that on two occasions we made service tests on 1.00 per cent carbon, 0.2 per cent vanadium steel and much to our surprise the average life was about 25 per cent below straight carbon steel. We have also tried upsetting dies. We procured a block of steel and upset it, in our endeavor to avoid the porous condition at the center of the die stock. At another time we cut the dies from the side of a block of steel. This permitted us to sink the die cavities across the grain instead of with it. We found that our results in both cases were about the same as when vanadium was present, namely three-fourths of our normal die life, causing us to draw the conclusion that a satisfactory die for our purpose should have its length conform to the direction of the original working of the metal.

UNANNOUNCED SPEAKER About how many balls do you get out of an average die?

MR. FREELAND An average die will produce from 30,000 to 50,000 balls of ½-inch diameter.

MR. WEBSTER How do they fail?

MR. FREELAND They fail by two methods. In one case the cavity of the die at the point of contact of the slug, checks; in the other case, their failure is caused by the cavity sinking under the impact.

MR. WEBSTER Have you attempted to rework these dies and do they last longer after reworking?

MR. FREELAND We rework them except in cases where they crack.

With reference to the life of a die after being reworked, I do not believe there is much difference. When dies fail, the failure usually occurs during the first 20 minutes of service.

MR. WEBSTER Do you find a wide variation in the production of dies made from the same bar of steel?

MR. FREELAND I would say yes. Sometimes it is more marked than at other times. I think that one of the reasons why the die probably fails so quickly is because the cavity is sunk in the weakest part of the section where the most porosity exists; namely, the center of the bars.

MR. WEBSTER Do I understand that you run these dies in relays?

MR. FREELAND We usually run the dies until they fail or require redressing, except when changing to another ball size.

MR. WEBSTER I was just wondering if it was a fatigue test.

MR. FREELAND Yes, it is practically a fatigue test because they are usually run to destruction.

MR. WEBSTER About what Brinell hardness do you use?

MR. FREELAND The scleroscope hardness at the cavity is in the neighborhood of 85. I do not know the exact Brinell value.

MR. WEBSTER Have you experienced any difference in the quality of the ball where you use different heading rates?

MR. FREELAND The only way that I can answer that question is to say that a 5/8-inch ball is formed at the rate of about 80 a minute; the smaller sizes, say from 1/4 inch to 1/8 inch, at about 135 a minute. We require a minimum crushing pressure in the hardening room test of heat treated balls and the same formula applies to all sizes between 1/8-inch and 1 1/4-inch balls, and all balls which are released must meet this requirement, so I do not believe that the rate of upsetting, within the limits we use, affects the quality of the ball.

MR. WEBSTER I presume the number of diameters you have in the slug to upset would have something to do with it.

MR. FREELAND Yes. The finished ball diameter is about 55 per cent greater than the diameter of the slug from which it is made.

MR. WEBSTER The number of diameters would have to be approximately close to two, I imagine.

MR. FREELAND I could not say exactly. We have determined a series of slug lengths for different sizes which will feed correctly and press well without buckling, etc. I would say that the factor is probably two to two and one-half times.

MR. WEBSTER Does your experience in forming this wire indicate that the flash is more pronounced on one side than on the other?

MR. FREELAND No. Usually the ball blanks are well balanced. Any case where the flash is more pronounced on one side than the other would be caused by displacement of the dies. A number of things might produce this, for instance, stock of irregular hardness would tend to shock the machine in such a manner as to displace the dies slightly.

MR. WEBSTER Sometimes in drawing wire the radius of the drawing die is eccentric to the hole of the drawing die, and it gives you eccentricity of draw, and for this reason the wire is of different hardness on one side than it is on the other. I was just wondering if this made enough difference to affect ball production.

MR. FREELAND I have no reason to believe that it does. I believe the trouble we experience from hard sections in the wire is of different source.

UNANNOUNCED SPEAKER I would like to ask the gentleman what his idea of a good steel for headers is.

MR. FREELAND The header man is looking for a steel that will stand a tremendous amount of shock. The die cavity has to resist the tendency toward distortion in service, which is quite great. The die should not break under impact, neither should the cavity crack, check or sink, and the bottom of the cavity at the junction of the knockout pin hole must not peen over in service. A straight carbon steel most closely meets these requirements.

UNANNOUNCED SPEAKER Mr. Chairman, I would like to ask the speaker just what is the manner of ball inspection?

MR. FREELAND The balls are inspected by visual examination, that is, the balls which are sent to the customers to fill their orders. They are examined on plates equipped with special reflectors arranged in such a manner as to counteract the glare caused by the bright light shining upon the mirror-like surface of the balls. The balls are revolved by moving a flexible card upon which they rest, thus exposing all parts of their surfaces

to view. The girls who do this work become very accurate in identifying balls having soft sections, seams, laps, or any defects. It takes six months to train a girl for microinspection, that is, a girl who is capable of inspecting our highest grade balls without the necessity of having her work continually checked. The way we maintain our standards is by the laboratory checking every day the different sizes of balls being inspected. The examination in this case is chiefly for concealed defects, that is, defects in the ball which are not visible to the inspector. The surface hardness, crushing loads and fractures are also checked at this time.

UNANNOUNCED SPEAKER Do the soft spots show up in a visual examination?

MR. FREELAND Yes. They show up in two ways. In one case the soft areas have a battered appearance, while in the other case the color is different. A soft spot on a ball is usually a darker color than the remainder of the highly polished surface. Possibly it is the troostitic condition of the steel at the point of softness that makes it actually darker.

MR. DANSE Is that 100 per cent inspection on each and every ball?

MR. FREELAND Yes.

MR. DANSE Do you use the bounce test for hardness?

MR. FREELAND No. The only time when this apparatus is used is when somebody in the plant accidently mixes hard and soft balls and it is necessary to separate them. This test is very interesting and possibly something could be developed from it. During the war it was necessary to furnish a few thousand balls which had to be super-hard. As I remember it, the ball size was ½ inch. Our regular balls passing through production were of such uniform hardness that ordinary inspection methods would not differentiate between balls which were slightly harder than our normal stock. In this case we used the bounce test by means of which we were able to separate accurately balls which were two points, scleroscope, harder than their fellows.

In this test the balls roll down a groove from which they drop to a hardened steel block and bounce from there over a hurdle-like arrangement into a box. Only the hardest balls are capable of passing over the hurdle. We found after we had bounced the balls six or seven times that all balls with soft spots were removed, and we were unable to determine the existence of any difference in the remaining balls by use of the scleroscope.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A DISCUSSION OF LANCELOT W. WILD'S PAPER ENTITLED "THE INFLUENCE OF HEAT TREATMENT UPON THE MAGNETIC PROPERTIES OF STEEL"

By N. J. Gebert

MR WILD states that the measurement of permeability and residual magnetism cannot be measured accurately except in ring form, or very long rods, which must be measured in pairs. The writer wishes to call attention to the fact that the latest developments of magnetic testing prove that this can be done on single specimens not in ring form, and also on almost any length. Scientific Papers of the Bureau of Standards No. 306, entitled "An Experimental Study of the Fahy Permeameter" is quite descriptive of an outfit which will make permeability and residual magnetism tests. Since the publication of this paper, the Fahy Permeameters have been further developed, and absolute accuracy can be obtained. This latest development of magnetic testing shows that accuracy can be obtained on material of the highest permeability and materials of low permeability with no change in the set up. This applies to the best Norway iron, silicon sheets for transformers, and electrolytic iron.

The writer is at a loss to account for the values of magnetic intensity which are shown on Table II. In my paper, printed in the *Journal of the American Steel Treaters' Society*, June, 1919, to which Mr. Wild refers in his bibliography, there is a direct comparison on the same kind of steel. I refer to nickel steel of 0.42 per cent carbon and 3.58 nickel. Mr. Wild shows reading of magnetic intensity of 20.7 with the draw 100 degrees Cent., a reading of 20.75, with a draw of 200 degrees Cent., whereas measurements which I have made show a reading of 17,000 Gauss per square centimeter at 100 degrees Cent. draw, and 19,900 with a draw of 200 degrees Cent. Also at draw of 300 degrees Cent., Mr. Wild shows a reading of 20.9, whereas I attained 20,050. It would, undoubtedly, be very difficult to observe the small differences of magnetic intensity which Mr. Wild shows, as the results which were shown in my method of testing, using the Fahy Permeameter, give much greater differences.

Mr. Wild further states that the galvanometer employed was not sufficiently sensitive to bring out the changes that really occurred in the coercive force of iron. This may account for his very slight differentiation in the magnetic intensity at various drawing temperatures, as the outfit which I employed was sensitive enough to test the coercive force, permeability, residual induction, etc., of any magnetic material.

A written discussion of Lancelot W. Wild's paper presented by title at the Indianapolis Convention and published in TRANSACTIONS May 1922. The author, N. J. Gebert, is metallurgist, American Chain Company, York, Pa.

Mr. Wild's results on the values of coercive force—Table III—agree very closely with the results which the writer obtained. Therefore, I am at a complete loss to understand his readings on magnetic intensity, unless Mr. Wild's outfit, particularly the galvanometer, is not sensitive enough to record accurately the slight differences in magnetic intensity.

AUTHOR'S REPLY

Mr. Gebert is a strong advocate for the Fahy permeameter. Though I admire the ingenuity that has been displayed in the development of this apparatus, yet I am sorry to be unable to endorse Mr. Gebert's good opinion of it when applied to heat-treatment problems.

I know the Fahy permeameter. The Bureau of Standards have very kindly kept me supplied with all their publications from the commencement (for which I am really grateful), and as I have been rather specializing in magnetic testing for more than twenty years, I have naturally followed with keen interest all developments of this nature.

Like most other magnetic testing apparatus, the Fahy permeameter suffers from the disability that the liability to error increases as the length of the test specimen is decreased. Frankly I should consider it beyond my powers to obtain systematic accuracy on test pieces measuring 1 x ¼ inches with the Fahy apparatus.

For the investigation of the "why and the wherefore" of steel hardening I have so far found that the measurement of saturation intensity has proved the most fruitful in results. For this measurement I require to employ short specimens. If on the same test pieces I could obtain the permeability at 1 or 2 points on the magnetization curve and the residual magnetism as well, I should certainly like to have them, although I do not at present see what would be gained. I do not, however, see my way to obtaining the precision required without materially lengthening the specimens.

Mr. Gebert appears to be surprised that when measuring inductions in unsaturated steel, he obtains values over a wider range than I obtain for measurements of saturation intensity. This appears to me perfectly natural.

With unsaturated steel the flux density depends upon two factors, namely, the ultimate magnetizability of the steel, and the mobility of the molecular magnets (a vile phrase but orthodox).

My measurement of saturation intensity implies the magnetizability of the steel alone and undiluted. It appears to me the better plan to measure ultimate quantities singly when one can do it. Mr. Gebert's permeability measurements really require analysis into their two components, an analysis which no one has yet succeeded in effecting.

In short, I am not out to obtain haphazard value ranges only, but to obtain values which can be reduced to fundamentals and employed for the purpose of analysis, the ultimate goal being a complete explanation of all the structural changes that take place in steel when heated and quenched under all sorts of conditions.

Since my paper was written about a year ago, I have made considerable advances in this direction, but I am not yet quite prepared to face destructive criticism of my analytical methods.

Mr. Gebert appears to have rather missed the point in his reference to my tests on iron. The tests for saturation intensity were carried out with the utmost care and very high precision, it being particularly desired to ascer-

(*Continued on Page* 928)

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?

QUESTION NO. 33. What is the role of nickel in steels?

QUESTION NO. 34. What is meant by the critical range or transformation range in a steel?

QUESTION NO. 35. What is the difference between red annealed and blue annealed sheet steel?

QUESTION NO. 36. Can mixed lots of steel be identified with a certainty by the aid of the grinding wheel spark test?

OLD QUESTIONS AND ANSWERS

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 10. What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?

ANSWER. By W. S. Bidle and B. F. Weston. Although experience had shown that there should be little if any difference in the rate of carbon penetration when treated under the same conditions, on the same steel whether it be cold rolled or drawn or hot rolled or machined condition several test pieces were submitted to a carburizing treatment, to check up this assumption. Mr. Weston, metallurgist of the Union Drawn Steel Company, reported the results of his tests as follows:

Steel specimen No. 1 was a 13/16 inch round hot rolled bar which was drawn to ¾ inch in diameter having a carbon content of 0.20 per cent and a manganese content of 0.47 per cent.

Steel specimen No. 2 was of the same size as No. 1 having a carbon content of 0.21 per cent and a manganese content of 0.58 per cent and a nickel of 3.38 per cent.

Steel specimen No. 3 was of the same size as the first two and of the ordinary screw stock analysis.

Before drawing steel No. 1 the hot rolled bar was pickled to remove scale. Each of the specimens were cut 4 inches long and were packed in a car-

burizing material made by a well known company allowing 1 inch of material between the side of the box and between each specimen. The box was placed in the heating furnace with a pyrometer thermocouple nearly touching the box and was heated for 4¼ hours from the time it had reached 1700 degrees Fahr. The box was allowed to cool in and with the furnace.

A section ½ inch thick comprising ½ the area of each bar was polished and etched and the depth of penetration was measured by means of a micrometer microscope at a magnification of approximately 27 diameters. The following results were obtained:

Steel No. 1 Hot Rolled depth of case	0.033 inch
Steel No. 1 Cold Drawn depth of case	0.034 inch
Steel No. 2 Hot Rolled depth of case	0.044 inch
Steel No. 2 Cold Drawn depth of case	0.047 inch
Steel No. 3 Hot Rolled depth of case	0.034 inch
Steel No. 3 Cold Drawn depth of case	0.037 inch

These measurements were made by two observers and it will be seen that a very slight difference if any, was observed in the depth of the case between the hot rolled and cold drawn specimens.

Mr. Bidle reports the result of a similar test which had been made in his plant on some Bessemer screw stock. The specimens had been prepared by taking the end off of the bar after being pickled and the adjoining end off of the same bar after it had been cold drawn. One specimen was left as pickled, one pickled bar was turned, one bar was left as cold drawn and the final piece was turned down slightly after cold drawing.

All of these specimens were packed in the same carburizing box heated to the carburizing temperature and cooled in the box and subsequently all four pieces were heated side by side and quenched.

As there were no accurate means available for measuring the depths of case of these specimens, they were visualized by several different observers and in all cases the depth of penetration appeared to be identical.

This result checks up many years of experience in practical carburizing and heat treatment and appears to be the results which have been obtained by many other observers. Therefore we believe that there is very little if any difference in the rate of penetration on bars having different mechanical treatments.

QUESTION NO. 12. *How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?*

QUESTION NO. 23. *Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?*

QUESTION NO. 24. Do steels of similar composition respond similarly to case hardening operations, and providing these are properly conducted, will satisfactory results always be obtained?

ANSWER. This question is answered quite fully in a paper presented by E. W. Ehn at the annual meeting of the Iron and Steel Institute in May, 1922. This paper shows that certain steels although complying in all respects with the usual specifications regarding chemical and physical properties, are quite unsuitable for carburizing.

One of the chief causes for the failure of steel of the low carbon content to harden after it has been carburized, is due, to improper deoxidization of the steel during melting. While the usual specifications for carburizing steel are as follows:

	Per Cent
Carbon	0.15 to 0.20
Manganese	0.35 to 0.65
Phosphorus, below	0.040
Sulphur, below	0.040
Silicon	0.005 to 0.010

there is no mention of the oxygen content. The degree of deoxidization of the steel affects directly all of the important factors which contribute to a properly carburized steel, such as maximum carbon content, depth of case, structure of the case and core and the way in which the carburized piece responds to final hardening.

An extensive examination was made in an effort to determine the conditions which frequently caused the rejection of carburized parts, due to soft spots even after extreme care had been exercised in carburizing and hardening. At first these failures were attributed to improper carburizing and hardening practice but later was definitely determined as due to an inherent property in the steel itself.

Further investigation proved that the difficulties were traceable to the ingot and that the cause or effect of the difficulty was not removed in any successive operations or treatments. It was found that the presence of soft spots in the steel was always accompanied with a special fine-grained structure in the carburized part. Steel showing such a characteristic would be classed as abnormal although it apparently was of the same composition as a steel having a uniform hardness after the same treatment. Poorly or insufficiently deoxidized steel while having apparently the same composition as a well deoxidized steel will give erratic results and almost always produce soft spots in the final product.

QUESTION NO. 25. What is the difference between magnification and enlargement in taking photomicrographs?

ANSWER. By Walter M. Mitchell, Philadelphia, Pa.

In the customary use of the word "magnification" we refer to the direct magnification (apparent increase in size) of the object examined. If recorded by photography the magnification represents the number of times that the photographic image of the object is larger than the object itself. This is al-

ways considered in linear dimensions; i. e. diameters, and not in areas. The greater magnification, the smaller the details of the object that will be made visible until the limit of resolving power is reached, after which no further details will be made visible no matter how much the magnification is increased. The resolving power is the ability to separate and render distinct; i. e. to "resolve" the finest details of the object. It depends upon the physical properties of light and the constants of the microscope and is independent of the object itself. "Enlargement" as ordinarily used means enlargement, or magnification, of the photographic negative. Such enlargement can show only such details as are actually on the photographic negative. Due to the fact that the grains of metallic silver of which the photographic image is composed have a finite size there is a practical limit to the degree of enlargement which it is advisable to make. This will probably be about 7 to 10 times; above this the silver grains become conspicuous and give the resulting photograph a granular appearance. Briefly, increased magnification will show finer details of the object itself, while enlargement can show no other details than those already on the photographic plate.

QUESTION NO. 26. Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 28. What is the role of manganese in steel?

In addition to the deoxidizing effect and also the desulphurizing effect of manganese in ordinary steels, wherein considerable of the manganese combines with sulphur forming MnS it is found that when manganese occurs in excess over the amount that is needed to form MnS with the sulphur content present, the excess manganese combines with some of the carbon forming Mn_3C and this carbide is found associated with iron carbide Fe_3C, in cementite. The prime effect, therefore, of manganese subsequent to its beneficial assistance in melting, is its effect upon the mechanical properties of steels. These effects pertain to varying percentages of manganese and are believed to be primarily due to the retarding action of this element on the transformations and on the coalescence of the micro-constituents into progressively coarser masses, which while increasing the ductility it lessens the cohesion in general, including the hardness and elastic limit, and thus lessens the effective strength.

Manganese like most of the alloying elements such as carbon and nickel retard the transformation of steel in heating and cooling. In a steel containing 2 per cent manganese with 2 per cent carbon the transformation is so retarded the austenitic state is preserved when quenching thin sections. In a steel containing from 5 to 7 per cent manganese the transformation is so slow that even air cooling only goes as far as the intermediate martensitic state, which accounts for the brittleness of steels containing an intermediate amount of manganese. With a 12 to 13 per cent manganese content the transformation is so slow that the austenitic state is preserved through slow cooling. Water quenching of a manganese steel of this composition is done for the purpose of suppressing the precipitation of the iron-manganese

carbide, cementite, which occurs on slow cooling, and not for the purpose of retaining an austenitic state. Broad plates of this cementite embrittle the mass by forming partings of low cohesion.

The commercial value of this higher manganese content steel seems to be due to its combination of high ductility with great effective hardness. Initially this steel appears rather soft, having a Brinell hardness of 125 on undeformed metal while this hardness increases very decidedly as a result of a small amount of deformation.

The hardening of manganese steel due to deforming, resembles in part the same course which leads to the increase of cohesion in general, including hardness, of all of the malleable metals undergoing deformation, such as wire drawing, and in part the martensitization of austenite. The retarded transformation from austenite through martensite to the alpha state due to cooling through the transformation range, is held back by the retarding action of manganese but is stimulated by any deformation to cause it to proceed as far as the martensitic state, thus causing hardening and embrittling. Martensitization by deformation thus stimulating arrested transformation is a common property of austenitic steels which have but a small excess of the retarding elements over the quantity needed for the retention of the austenitic state.

QUESTION NO. 29. Does the macrostructure of a piece of steel ever reveal imperfections which cannot be observed under the microscope or through chemical analysis?

ANSWER. The macrostructure, or the structure which is developed by polishing and deep etching with a suitable etching agent, a specimen of steel under examination very frequently reveals imperfections in the material which are not detected through the ordinary methods of chemical, physical and microscopic examinations. The fibrous structure is revealed by this type of etching as well as any dendritic conditions which may be of such a nature as to be detrimental. Full sized specimens, forgings, castings, etc., may be treated by this method permitting an examination of flow lines or excessively large dendrites. Dilute solutions of sulphuric acid, nitric acid, hydrochloric acid, ammonium copper sulphate, tincture of iodine, etc., are the usual reagents used. This method of testing is rapidly coming into extensive use.

QUESTION No. 30. How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION No. 31. What is the effect of oxidizing gases at low pressure on heated iron?

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

HEAT TREATING PROBLEMS

RELATION OF TIME FOR HEATING ROUND SECTIONS TO SURFACE PER POUND OF STEEL EXPOSED. By E. J. Janitzky, FORGING AND HEAT TREATING, Vol. 8, Page 179.

Using data presented by M. E. Leeds in a paper entitled "Some Neglected Phenomena in the Heat Treatment of Steel," an equation is developed giving the time required to bring steel to heat in terms of surface and lag for a given temperature.

$$\text{Time} = \frac{5.3 \text{ (a constant)} + \text{Lag (a quantity depending on temp.)}}{\text{Surface in sq. in. per pound of steel}}$$

MODERN METHODS OF MAKING LEAF SPRINGS. By E. F. Lake, IRON AGE, Vol. 109, Page 1269.

The plant of the American Auto Parts Co. is described. The forming (except for the eyes) and hardening operations are accomplished with a single heating of the steel. The heating operations both for hardening and tempering are carried out in oil fired furnaces of the intermittent type. After tempering the springs are assembled and tested.

METALLOGRAPHY AND HARDNESS THEORY

A DISCUSSION OF THE SLIP INTERFERENCE THEORY OF HARDENING. By P. D. Merica, CHEMICAL AND METALLURGICAL ENGINEERING, Vol. 26, Page 881.

Merica considers that the keying action alone of the dispersed particles is not sufficient to account for hardening, and that cohesive forces between the key particles and the matrix must be considered as playing an important part. Two additional points; the fact that maximum hardness does not involve minimum ductility and that extreme cold work causes softening, are brought up.

CRYSTAL GROWTH IN METALS. By G. R. Fonda, GENERAL ELECTRIC REVIEW, Vol. 25, Page 305.

Crystallization the effect of cold work on crystal structure, recrystallization, and grain growth are discussed in a general way. No new data is presented. A well selected bibliography is given.

ON DELAYED CRYSTALLIZATION IN CARBON STEELS: THE FORMATION OF PEARLITE, TROOSTITE AND MARTENSITE. By A. F. Hallimond, Presented at the May Meeting of the Iron and Steel Institute (London).

The analogy between the equilibrium relations of a ferrite, cementite and austenite, and two mutually insoluble solids, crystallizing from a liquid solution, is well established, but similar relations for martensite and troostite are not yet well recognized. Study of the principles underlying "delayed crystallization" offer possibilities. Investigations have developed that two regions, the metastable and the labile separated by the supersaturation curve are to be found below the stable equilibrium lines for many pairs of substances. A zone is also to be found in the metastable area in which the effect of inoculation (with an isomorphous substance) becomes apparent. On reaching the labile area, the substance in solution will separate as a shower of crystals. On this basis, martensite is interpreted as being a labile shower of a-ferrite and troostite as a labile shower of cementite.

METALLURGICAL EDUCATION AND RESEARCH

STEEL FOUNDRIES CO-OPERATE IN JOINT RESEARCH. By D. M. Avey, IRON TRADE REVIEW, Vol. 70, 1471.

The Electric Steel Co. (Chicago), The Fort Pitt Steel Castings Co.

(McKeesport, Pa.), The Lebanon Steel Foundry (Lebanon, Pa.), The Michigan Steel Casting Co. (Detroit), and the Sivyer Steel Castings Co. (Milwaukee) make up the group. The method of co-operation is outlined. Maj. R. A. Bull has been retained as advising expert. Problems investigated to date include abrasives, annealing, core practice, facing sand, furnace practice, and the effect of the presence of slag in castings.

STEELS

STEEL FOR FORGE WELDING. By F. N. Speller, Blast Furnace and Steel Plant, Vol. 10, Page 259.

As a result of some 80 tests it was found that steel of 0.15-0.20 per cent carbon is best suited for forge welding. Suitable material, well-trained operators, and adequate control facilities are essential for the uniform production of such welds.

STEEL FOR CRANK SHAFTS: ITS HEAT TREATMENT. By H. C. Loudenbeck, Forging and Heat Treating, Vol. 8, Page 181.

Three classes of steel are used in crank shafts: (1) carbon steel, annealed or hardened, (2) carbon steel, case hardened, and (3) alloy steels, heat treated. In class 1, S.A.E. 1035-1045 is used, in class 2, S.A.E. 1020 is used, and in class 3 the most commonly used is nickel chrome steel such as S.A.E. 3135. Chrome molybdenum and chrome vanadium steels are also used. The heat treatment and physical properties for each class of steel are given.

BALL BEARING STEEL AND ITS HEAT TREATMENT. By C. T. Hewitt, Forging and Heat Treating, Vol. 8, Page 196.

Steel used for ball bearings and races is usually high carbon steel, containing 0.60 to 1.50 per cent chromium. The lower chromium steels are used for the balls. The annealing and hardening operations used are described in general terms.

THE USE OF MOLYBDENUM STEEL IN THE AUTOMOTIVE INDUSTRY. By J. D. Cutter, Journal Society of Automotive Engineers, Vol. 10, Page 340.

The use of chrome-molybdenum steels are recommended for automobile frames, a considerable reduction in weight being made possible thru their use. Carbon molybdenum steels are recommended for pressed steel parts. Manufacturing costs are said to be reduced thru the use of molybdenum steels due (a) to their wide heat treating range and (b) their ease of machining. A discussion of the article is given.

TESTS ON FERROUS MATERIALS

RECENT RESEARCHES ON STATIC NOTCHED BAR TESTING. By H. A. Holz, Chemical and Metallurgical Engineering, Vol. 26, Page 941.

Curves showing the results obtained by pulling notched test pieces (Izod type) in a static machine are presented. More valuable data can be gained thru the use of the static machine since one can follow the test step by step, a thing not possible with impact machines.

THE RESISTANCE TO TORSION AND BENDING OF STEELS BETWEEN ROOM TEMPERATURES AND VISIBLE RED. By M. J. Seigle, Revue de Metallurgie, Vol. 19, Page 178.

A method is described for demonstrating in a striking way the influence of temperature on the properties of steel. If small single groves are filed in uniform rods to be tested in torsion and sections of these rods heated while being twisted, the grove will form a helix with turns closest together in that part of the rod which the temperature had rendered the most ductile. Similar tests may be carried out in tension, except that here a series of small nicks are spaced at even distances along the rod.

THE TESTING OF DROP FORGINGS. By Leslie Aitcheson, Forging and Heat Treating, Vol. 8, Page 188.

The tests which may be carried out advantageously on drop forgings are (a) chemical analysis, (b) physical tests, (c) microscopic examination, (d) macroscopic examination, (e) service tests, and (f) design tests. Tests a and b are recommended for the raw steel, tests b, d, e, and f for the drop forgings, and tests c, e, and f for forgings which fail in service.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ALLEN, C. A., (M-5), 73 Sigourney St., Hartford, Conn.
BARKLING FUEL ENGINEERING CO., (S-5), 1743 N. Kenton, Ave., Chicago, Ill.
BARTON, C. R., (M-6), Standard Seamless Tube Co., Ambridge, Pa.
BELKNAP, R. E., (A-6), 1917 Peoples Gas Bldg., Chicago, Ill.
BOLLINGER, P. G., (M-5), 2013 4th Ave., Altoona, Pa.
BRANCH, T. H., (S-6), Pullman Car Works, Pullman, Ill.
BRANDT, P. L., (Jr-5), 505 6th St., Washington, D. C.
BURKHARDT, F. C., (M-4), The Crosby Company, Buffalo, N. Y.
CALKINS, C. H., (M-5), Bausch Machine Tool Co., Springfield, Mass.
CORNISH, F., (M-6), 3 Greenwood Avenue, Blue Island, Ill.
CROSBY, V. A., (M-6), 1252 Lincoln, West, South Bend, Ind.
DAY, J. R., (M-6), 15315 Turlington Ave., Harvey, Ill.
ELY, HEMAN, Jr., (A-6), Electro Alloys Co., Elyria, O.
FREY, A. A., (M-5), 1115 Wallace Ave., Wilkinsburg, Pa.
GOESEL, H. G., (M-6), 37 San Francisco Ave., Blue Island, Ill.
GRANGER, L. D., (M-4), 69 Hammond St., Worcester, Mass.
GREVE, MAX, (M-6), 162 Biddle (Apt. 19), Milwaukee, Wis.
HAMILL, T. E., (Jr-5), 430 Manor Place, N. W., Washington, D. C.
HASSLER. L. W., (Jr-6), 728 Fullerton Ave., Chicago, Ill.
HEBBARD, Wm. T., (M-6), 324 12th St., S., Washington, D. C.
HERMAN, G. N., (A-6), 1140 W. Washington Blvd., Chicago, Ill.
HOMMERBERG, V. I., (M-6), Massachusetts Inst. of Tech., Cambridge, Mass.
HOOVER, Wm., (M-4), American Rolling Mill Co., Middletown, O.
KAISER, H. F., (Jr-6), Lewis Institute, Chicago, Ill.
KINGSBURY, S. S., (Jr-5), Bureau of Standards, Washington, D. C.
KOLF, P. (M-5), Independent Pneumatic Tool Co., Aurora, Ill.
LASCHUK, SEDOR, (Jr-6), 904 W. Milwaukee, Chicago, Ill.
LAWRENCE, F. L., (M-5), Frost Gear & Forge Co., Jackson, Mich.
LECKINGER, LEON, (M-5), High Speed Hammer Co., Inc., Rochester, N. Y.
LEONARD, S. C., Jr. (M-4), 5418 E. View Park, Chicago, Ill.
LINDHOLM, G. F., (M-6), 4711 N. Seeley Ave., Chicago, Ill.
LOUGHREY, D. R., (M-5), 5538 Black St., Pittsburgh, Pa.
MAYER, C. A., (S-5), American Bosch Magneto Corp., Springfield, Mass.
McARDELL, W., (Jr-6), 15 Argyle Rd., Brooklyn, N. Y.
McBRIDE, (M-6), Colorado Bldg., Washington, D. C.
MORRELL, C. P., 511 Bulkley Bldg., Cleveland, O.
MUTCHLER, W. H. (Jr-5), Bureau of Standards, Washington, D. C.
NUTH, A. C. (M-5), 12046 Stewart Ave., Chicago, Ill.
PENNINGTON, T. W., (M-6), 1201 Fayette St., N. S., Pittsburgh, Pa.
PERETTO, ROBT., (M-5), 9021 Wilson, Dearborn, Mich.
PITTS, C. M., (M-5), Althea Ave., Gardenville, Baltimore, Md.
REMSEN, C. A., (S-6), 612 Albee Bldg., Washington, D. C.
ROSENBERG, S. J., (Jr-5), Bureau of Standards, Washington, D. C.
ROSSER, H. M., (M-6), Bureau of Standards, Washington, D. C.
SCRIMGEOUR, Wm., (A-6), 410 Albee Bldg., Washington, D. C.
SODEN, C. P., (A-5), 217 Broadway, New York City.
SMITH, W. J., (Jr-6) 1963 Leland Ave., Chicago, Ill.
STACKHOUSE, W., (M-5), 6631 Marsden St., Tacony, Philadelphia, Pa.
STANDFUSS, E., (M-6), 2933 Chestnut St., Milwaukee, Wis.
SUZNICK, GEO., (M-4), 354 Ogden Ave., Ardmore, Wilkinsburg, Pa.
SZWAIKART, T. G., (Jr-6), 2718 Francisco Ave., Chicago, Ill.
TALLMAN, V. M. F., (M-1), 2-1 Devonshire St., Boston, Mass.
TAYLOR, T. D., (M-6), 1416 Otto Blvd., Chicago Heights, Ill.
THOMPSON, W. D. (M-5), Indiana Natural Gas & Oil Co., East Chicago, Ind.
TOMMET, A. J., (M-6), 806 N. Chicago Ave., S. Milwaukee, Wis.
TUCKER, W. A., (Jr-5), 1523 22nd St., N. W., Washington, D. C.

UNIVERSAL STEEL CO., (S-6), Bridgeville, Pa.
WHIPPLE, H. S., (M-6), Rockford Gas Light & Coke Co., Rockford, Ill.
WRIGHT, C. O., (M-5), Indiana Natural Gas & Oil Co., East Chicago, Ind.

MAIL RETURNED

FOSTER, W. H., 1321 Oliver St., Indianapolis, Ind.
JONES, J. H., 83 Main St., Bristol, Conn.
STEPAN, Roessler & Hasslacher Chemical Co., Chicago, Ill.

CHANGES OF ADDRESS

BARR, H. L., (M-11)—from Follansbee Bros., Co., Follansbee, W. Va., to Trumbull Steel Co., Warren, O.
BUELL, Wm. C., (A-5)—from Geo. J. Hagan Co. to Buell-Scheib-Muller, Inc., Columbia Bank Bldg., Pittsburgh, Pa.
EDELIN, J. W., (M-5)—from 407 Evans Bldg., to 311 4th St., Washington, D. C.
EDINGER, J. J.—from 300 Hudson St., to 102 Hartford Rd., E. Syracuse, N. Y.
FOSS, F. F.—from Russian Embassy, to Care Mr. David White, Room 4241 Interior Bldg., Washington, D. C.
HAWKINS, E. R., (M-4)—from 724 Delaware St., to 391 Adams St., Gary, Ind.
HOYT, H. S., (A-4)—from 745 Washington St., New York City, to A. Milne & Co., 17 N. May St., Chicago, Ill.
JOHNSON, P. A., (Jr-5)—from 4235 N. Springfield Ave., to 4933 N. Tripp Ave., Chicago, Ill.
JOHNSON, W. G., (M-3)—from 1811 Wyoming Ave., Washington, D. C., to Doehler Die Casting Co., Brooklyn, N. Y.
KIEFER, H. G., (M-2)—from 1030 Beaconsfield Ave., to 1300 Seward Ave., Detroit, Mich.
MARSHALL, G. D.—from 1444 E. 116th St., to 2484 Lee Road, Cleveland, O.
POLHEMUS, G. J.—from 1238 Washington Blvd., Chicago, to Care Barbee Steel & Iron Co., E. Water at Huron St., Milwaukee, Wis.
PUTNAM, W. S.—from Universtiy of Ill., Urbana, Ill., to New Salem, Mass.
RHODES, P. S.—from 2721 Catherine St., to 4832 Vinewood, Detroit, Mich.
RUBY, W. J., (M-2)—from 2174 E. Warne Ave., to 2019 E. John Ave., St. Louis, Mo.
STERLING, J. D., (A-4)—from Hoskins Mfg. Co., 410 Sloan Bldg., to 947 Leader-News Bldg., Cleveland, O.

(*Continued from Page* 919)

tain whether any nonmagnetic iron could be trapped by rapid quenching or otherwise.

On the other hand the tests for coercive force were not at all exact, as the same coils and galvanometer were used as for the hardest steels.

The method for measuring coercive force is, however, quite applicable to iron, merely an adjustment for sensitiveness being required. As a matter of fact, before this paper was written, I had already carried out quite an extensive investigation on the effect of heat treatment of iron, measuring the coercive force only by the method described in the paper. This was not added to the paper, as my desire was to do no more than to present a general survey of my subject.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering, Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

STANDING OF THE CHAPTERS

In the June issue of the TRANSACTIONS was published the standing of the chapters of May 1st. The list below shows the standing of the chapters on June 1st.

1. Chicago
2. Detroit
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. MILWAUKEE
9. **Boston*
10 **Lehigh Valley*
11. *Indianapolis*
12. *Syracuse*
13. Worcester
14. ROCKFORD
15. *Cincinnati*
16. **North West*
17. *SPRINGFIELD
18. *Tri City*
19. Providence
20. WASHINGTON
21. **St. Louis*
22. *New Haven
23. BUFFALO
24. *Schenectady*
25. Toronto
26. South Bend
27. Rochester
28. Bridgeport

*=Tied

The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on May 1st. Those shown in italics are not occupying as high a position as in the previous report. Those printed in regular type (i.e. Chicago) are occupying the same position as in the previous report.

May was the best month for increase of membership the Society has had during the past year. One hundred and thirty-fiive new members were reported with dues paid, while about 40 applications were received not accom-

panied by dues and who did not remit before the first of June and consequently are not included in this report.

We all realize that business conditions are opening up and in a number of cities have opened up and we believe that you will agree that 'the time to strike is when the iron is hot,' and it is desirable for the chapters to continue their membership activities during the summer months. It should be an easy matter to continue the wonderful progress made in May, because two very important reasons: (1) that of receiving the TRANSACTIONS containing the Convention papers as well as (2) that a membership starting now will give the new member the advantage of all chapter meetings during the coming year, can be offered now and should make the securing of new members an easy proposition.

The largest increase of any chapter was shown by Chicago where 32 new members were added during the month.

Milwaukee is to be congratulated on changing its position from 12th in the last report to 8th on this report passing Indianapolis, Boston, Lehigh Valley and Syracuse.

Washington also made a very commendable record during the month having broken the tie in which they were involved during the last two reports and advanced their position from 23rd to 20th passing in the interim St. Louis, Schenectady and New Haven.

One of the pleasant observations to be made is that there is constantly being received at headquarters a large number of applications forwarded by individuals who are not members of Membership Committees but who in the course of their travels bring the Society to the attention of interested individuals.

All members of the Society should bear in mind that the railroads have granted fare and one-half for the round trip to the Detroit Convention but these certificates entitling the low fare are issued to members. So if you are acquainted with anyone who is going to the convention he will be able to more than save his year's dues by the reduction he will obtain by becoming a member of the Society and getting reduced rates to Detroit. And then again he will almost save his year's dues by the special privileges and advantages that will be offered to members at Detroit for which other individuals will have to pay.

BOSTON CHAPTER

At the annual meeting of the Boston Chapter which was held May 26th at the Boston City club, the election of officers for the ensuing year took place. Those members elected to office are as follows: Chairman, Z. L. Sault, New England Annealing & Tool Company; vice chairman, H. W. Porter, H. K. Porter Company; secretary-treasurer, W. J. Kunkel, Blake & Knowles Co.; executive committee, W. W. Cummings, Boston Consolidated Gas Company and E. E. Roberts, New England Metallurgical Corporation.

It was at this meeting that Mr. J. C. Spence of the Norton Company presented his very interesting paper entitled "Grinding Practice."

CHICAGO

At a recent meeting of the Chicago Chapter, the following members were elected as officers for the next year:

Chairman, H. F. Wood, Wyman Gordon Company; vice chairman, F. G.

Wheeler, 1953 Hastings street; secretary-treasurer, H. Blumberg, Illinois Steel Company; executive committee, A. G. Henry 3609 Lake Park avenue, E. J. Janitzky, Illinois Steel Company, M. E. Williams, 504 Oakwood boulevard, George Charlton, 2503 South Wood street, H. T. Moore, 760 Polk street.

The first annual outing of the Chicago Chapter was held on the afternoon of June 10 at the Hartman House, Wheeling, Ill., which is about twenty-two miles from the loop on Milwaukee avenue. A large number of tickets had been sold and about 250 members and guests were taken to the Hartman House by automobile. These automobiles were furnished largely by the members of the chapter.

The announcement of this outing stated that An Honest-to-God, Old Fashioned Home Cooked Chicken Dinner, and all that goes with it would be served at the Hartman House, and the announcement had not exaggerated it in any way.

After everybody had filled up on good things there were all sorts of entertainment, baseball, tennis and boating were available for everyone.

After a rousing good time indulging in and enjoying all of the out door sports available, the party returned to Chicago about 6:30. It was unanimously voted by all those who attended that they had had one grand time.

A detailed report of this outing will be given later.

CINCINNATI CHAPTER

The Cincinnati Chapter held it annual meeting in the rooms of the Ohio Mechanics Institute on June 8th. The speakers for this meeting were John C. Spence and C. H. Norton, of the Norton Company. Both men presented a paper entitled "Grinding of Steel." The paper proved to be exceedingly interesting and instructive and brought forth considerable new ideas on the grinding of steel and developed a large amount of discussion after its presentation. About 75 members and guests were present at this meeting.

Following the paper and the short order of business, the election of officers for the ensuing year was held. The members elected are as follows:

Chairman, Dr. J. C. Hartzell, Blue Ash, Ohio; vice-chairman, A. L. Myers, R. W. LeBlond Machine & Tool Company; secretary-treasurer, Fred L. Martin, 705 Elm Street; executive committee, C. H. Waldo, Ohio Knife Company; Edward Gardner, Modern Tool & Mfg. Company; W. J. Wersel, Allis Chalmers Mfg. Company; W. T. Cowell, Lodge & Shipley; E. W. Detraz, University of Cincinnati.

CLEVELAND CHAPTER

The Cleveland Chapter held its last meeting for the season on Thursday evening, June 1st in the ball room of the Hotel Winton. Following the regular order of business, Prof. H. M. Boylston presented a paper entitled "Migration of Carbon in Iron." This paper was the result of considerable research work at the Case School of Applied Science. Some very interesting facts regarding the migration of carbon in iron and steel were developed, and it is hoped that in the near future this paper may be printed in the TRANSACTIONS.

Professor Boylston's paper brought forth considerable discussion on the theory of the migration of carbon. Following this paper the final report of the secretary was read and approved. Reports from the various standing committees were also read. The report of the Nominating committee had

been presented at the previous meeting. It was moved that the recommendation of the Nominating committee be accepted unanimously. This motion was approved and carried. The officers for the ensuing year are:

Chairman, Prof. H. M. Bolyston, Case School of Applied Science; vice chairman, R. T. Bayless, 4600 Prospect avenue; secretary-treasurer, D. M. Gurney, Warner & Swasey Company; executive committee, C. G. Shontz, Perfection Spring Company, Wm. H. Brainard, Carnegie Steel Company, M. L. Burchfield, 1380 West Seventy-third street, V. M. Wellman, 1224 Oregon avenue, W. S. Bidle, W. S. Bidle Company, R. S. Archer, Aluminum Castings Company.

Following this order of business, the chapter was entertained by some professional performers who put on a very interesting and pleasing entertainment in the form of dancing and singing.

It was announced that the next meeting would be held in September.

DETROIT CHAPTER

The result of the annual election of officers of the Detroit Chapter was announced at the May 27th meeting of the chapter. They are as follows:

Chairman, J. L. McCloud, Ford Motor Company; vice chairman, Walter E. Jominy, Studebaker Corporation; secretary-treasurer, W. G. Calkins, Detroit Twist Drill Company; executive committee, J. M. Watson, Hupp Motor Car Company; H. M. Bray, Cadillac Motor Car Company; Robt. Atkinson, Maxwell Motor Company; F. E. McCleary, Dodge Bros.; R. E. Surtees, Studebaker Corporation.

On June 1, the Executive Committee held a meeting primarily for the appointment of the Papers & Meetings, Membership and Research Committees for the year 1922-23.

Bob Atkinson will have charge of the Papers & Meetings so we are looking forward to some very interesting meetings. W. E. Blythe will undertake the job of doubling our membership next year, and Walter Jominy will head the Research Committee.

We are looking for big things from the Detroit Chapter and from the excellent manner in which the convention arrangements are being handled, Detroit will have a wonderfully successful year as a result of their untiring activities.

HARTFORD CHAPTER

The May meeting of the Hartford Chapter was held Thursday evening, May 11th, in Jewell Hall, Y. M. C. A. Mr. James J. Curran, Metallurgist for the Henry Souther Engineering Company, delivered an excellent illustrated address on "The Inspection and Heat Treatment of Steel." Particular stress was laid on the value of deep etching discs cut from bar stock for revealing inclusions; pipes, seams, etc. The slides of the etched disc and microphotographs of the same were excellently prepared and very instructive.

The local Standards committee consisting of Messrs. Lanning, Green and Olsen submitted their report on the chemical specifications prepared by the National Standards committee. The following resolution on this subject of Chemical Specifications was voted on at this meeting and adopted by a unanimous vote. "Resolved that it is the concensus of opinion of the Hartford Chapter that efforts should be made to promulgate heat treatment specifications rather than attempt to promote new steel specificaions."

Mr. Arvid Anderson, chairman of the nominating committee, presented the names of the members nominated for office for the coming year and

the following men were elected: Chairman, A. H. d'Arcambal, Pratt & Whitney Co.; vice chairman, J. J. McIntyre, McIntyre Machine Co.; Secretary-treasurer, J. J. Curran, Souther Engineering Co.; Executive Committee, M. E. Gere, New Departure Mfg. Co., Bristol; H. I. Moore, Firth Sterling Steel Co.; Cyrus Blackman, Colts Patent Fire Arms Co., Elmwood; G. P. Moore, Wallace Barnes Co., Bristol; Theodore Jacobson, S.K.F. Ball Bearing Co.,Hartford; E. S. Lewis, Stanley Works, New Britain; R. K. Newman, Frasse Steel Works; L. A. Lanning, New Departure Mfg. Co.

Mr. David O'Brien of the Pratt & Whitney Co., came out with first honors in the heat treating contest held in March. Mr. O'Brien obtained 400 points, his nearest competitor being Mr. Anderson of the New Departure Mfg. Co. with 185 points. Mr. O'Brien was presented with a large box of cigars as a reward for his excellent work in this contest.

The annual banquet was held June 9 at 7 P.M in the ball room of the Bond Hotel. Mr. Charles Carpenter, President of the E. F. Houghton Company and Editor of "The Houghton Line" was the principal speaker of the evening. Mr. Carpenter is well known throughout the United States for his versatile editorials and his style of attack was indeed very entertaining. It was a privilege of the chapter to be able to have him with them.

Mr. Hathaway's Entertainment Committee promised special interesting features for this meeting and they surely did come across in good shape.

INDIANAPOLIS CHAPTER

The regular monthly meeting of the Indianapolis Chapter was held in the Directors' Room of the Chamber of Commerce, Monday, May 8. The meeting was opened at 8 o'clock by Chairman W. R. Chapin. The election of officers was held and the following men were elected for the ensuing year:

Chairman, P. O. Deeds of the Indianapolis Manufacturing Company, and secretary-treasurer, John Q. Holmes of Nordyke & Marmon Company.

After a short business discussion, Mr. Clark of the Norton Company was introduced and presented a very interesting talk on "Grinding and the Manufacture of Abrasives." His talk was illustrated with lantern slides. Following the paper an informal and interesting discussion resulted. Mr. Clark brought with him many interesting samples of ground work, illustrating results of proper and improper methods of grinding.

About 60 members and guests attended this meeting.

The regular monthly meeting for June was held in the rooms of the Indianapolis Chamber of Commerce on June 12. The meeting was opened by Chairman Paul O. Deeds and a short business session was held during which the discussion of plans for the ensuing year was brought out. In connection with this session a motion was carried that the chairman appoint a committee to draw up a simple glossary of technical and metallurgical terms that would enable the man at the fire to understand to better advantage the papers in the TRANSACTIONS and discussions at the meetings of the local chapter. This was done in an effort to interest the workmen in the Society with the hope of increasing the membership by obtaining such men as members.

Delegates to the Detroit Convention were appointed and are as follows:

A. L. Cramp and H. B. Northrup.

Following the business session, the meeting was turned over to Mr. H. E. Haywood of the Link Belt Company who explained the "Making of a Link Belt." This talk was illustrated with stereopticon slides and with photo

micrographic specimens which were examined through a metallographic apparatus loaned by Mr. Haywood. Following this paper a round table discussion took place. The meeting adjourned at 10:30 o'clock until September.

SPRINGFIELD

The Springfield chapter held its May meeting in the rooms of the Chamber of Commerce on the 26th. Mr. H. B. Byers, president of the New England Metallurgical Corporation, of Boston, was the speaker of the evening, and presented his paper entitled "Practical Points in Heat Treating." Mr. Byers had been long connected with the Watertown Arsenal and is at present connected with the New England Metallurgical Corporation where all kinds of commercial heat treating is handled, qualifying him in a very excellent manner to discuss the subject of his paper. It was presented in a very interesting manner and aroused considerable interesting discussion.

The last meeting of the Springfield Chapter was held on Friday evening, June 16th in the Chamber of Commerce Building. In accordance with the custom for the past two years, the final meeting of the season was a get-together meeting.

A very satisfactory report covering the year's work was presented by the secretary at this meeting, after which followed the election of officers. The new officers are as follows:

Chairman, A. E. Sanford, metallurgist, Hendee Manufacturing Company; secretary- treasurer, E. L. Woods, Springfield Gas Light Company.

A paper prepared by Mr. V. Malcomb, metallurgist of the Chapman Valve Manufacturing Company and entitled "Acid Electric Steel," was read by the newly elected chairman, on account of the author's absence.

Mr. E. L. Wood, metallurgist at the Springfield arsenal presented a short talk on "Methods of Determining the Elastic Limit of Steel in Tension and Its Use in Engineering Designs. The discussion following both talks was most interesting and instructive.

MILWAUKEE CHAPTER

On May 23, the Milwaukee Chapter of the American Society for Steel Treating held a joint meeting with the Milwaukee Chemical society in the banquet hall of the Republican house.

Mr. Zay Jeffries, Cleveland, of the Aluminum Company of America, was the speaker of the evening. His subject was "The Hardness of Metals," and his lecture was illustrated with lantern slides. By his talk and through the medium of his slides, he represented the various crystalline structure of metals. He emphasized treatment "as one of the most important features in the metal industry," and explained why certain treatments render the metal either hard, tough or elastic.

Nearly 100 of the manufacturing interests of Milwaukee were represented at the meeting.

NEW HAVEN

The final meeting of the New Haven Chapter was held Wednesday evening May 31st in the Cafe Mellone. A. H. d'Arcambal, chief metallurgist of the Pratt & Whitney Company, presented a paper entitled "High Speed Steel." This paper was illustrated with lantern slides and heat treated speci-

mens were passed around. It was announced that any who had been having trouble with high speed steel treating should come prepared with questions for discussion. This proved to be highly satisfactory inasmuch as a good lively discussion followed Mr. d'Arcambal's paper which brought out some valuable information pertaining to the heat treatment of high speed steels.

NEW YORK CHAPTER

The New York chapter held its regular June meeting in the assembly room of the Merchants Association of New York in the Woolworth building, June 21st.

Three very excellent papers were presented to the members assembled. They were as follows:

"Tool Room Troubles" by A. H. Kingsbury of the Crucible Steel Company of America, Pittsburgh.

"Carbonizing Practices" by John F. Wyzalek, Hyatt Roller Bearing Co., Harrison, N. J., and "Salt Baths" by Sam Tom, Dohler Die Casting Co., Brooklyn, N. Y.

These papers aroused a large amount of discussion and the meeting proved to be one of the best of the season.

NORTH WEST CHAPTER

The annual meeting of the North West Chapter was held Friday evening May 26, and the following officers and Executive Committee were duly elected to serve for the ensuing year:

H. Kenneth Briggs, chairman, Minneapolis Electric Steel Castings Co.; W. E. Johnston, vice-chairman, Mahr Manufacturing Company; Alexis Caswell, secretary-treasurer, 200 Builders Exchange Building; executive committee, Ralph Dowdell, University of Minnesota; Oscar E. Harder, University of Minnesota; J. C. Irwin, Thexton Manufacturing Company; Chester S. Moody, Minneapolis Steel & Machinery Company; N. H. Plouff, 17 East Lake Street.

The speaker of the evening was Mr. O. T. Muehlemeyer of Barber-Colman Company, Rockford, Illinois, whose subject was "Tool Hardening." Mr. Muehlemeyer's paper aroused much interest, and it is hoped that his paper will be published in the near future. The paper was written in a very interesting manner and aroused considerable discussion and was a very capable presentation.

The tenth and last lecture in the Educational Course was held Monday, June 12 at 8 o'clock at the Manufacturers' Club. Mr. Francis B. Foley of the U. S. Bureau of Mines, presented the lecture entitled "Alloy Steels."

These meetings have proved exceedingly interesting and beneficial to all who have availed themselves of this opportunity of attending and hearing the various men who presented lectures, discussing the subjects in which they are experts.

PHILADELPHIA CHAPTER

The last meeting of the Philadelphia Chapter was held Thursday evening, June 1st, in the Engineers' Club Auditorium. Mr. Jerome Strauss, metallurgist and chief chemist, Washington Navy Yard presented an illustrated paper on "Characteristics of Some Manganese Steels." Mr. Strauss is a

recognized authority on the subject of manganese steels and his paper gave

ARTHUR W. F. GREEN
Re-elected Chairman of the Philadelphia Chapter

some very important information relative to them. A very interesting and instructive discussion followed this paper. Following the paper of the evening

ARTHUR L. COLLINS
Re-elected Secretary-Treasurer of the Philadelphia Chapter

the following members were elected as officers for the ensuing year:

Chairman, A. W. F. Green, John Illingworth Steel Company; vice chair-

man, E. H. Barker,, A. H. Wirz, Inc.; secretary-treasurer, A. L. Collins, 5616 Crowson street; executive committee, J. J. Crowe, Philadelphia Navy Yard, W. M. Mitchel, 112 North Thirty-fourth street, D. K. Bullens, 909 West Tioga street, J. W. Barnett, 1228 Callowhill street, L. A. Cummings, Standard Steel & Bearings, Inc.

ST. LOUIS CHAPTER

The last meeting for the present year was held on June 8th at the Engineers' club. The speaker of the evening was Mr. W. W. Cox, Commercial Chemist, who presented a very capable paper entitled "Utilization of Pig Iron." Mr. Cox is a well known metallurgist in St. Louis and what he

C. B. SWANDER
Elected Chairman of the St. Louis Chapter

had to say about pig iron was very instructive. His paper brought forth considerable interesting discussion on foundry practice.

Following the paper of the evening the following members were elected as officers for the ensuing year:

Chairman, C. B. Swander, Wagner Electric Mfg. Company; vice chairman, Carl Krutzsch, St. Louis Frog & Switch Company; secretary-treasurer, G. S. Rogers, E. F. Houghton & Company; executive committee, Lor. Clarke, Leschen Wire Rope Company, F. Hanman, Mound Tool Company, F. A. Lawler, Crucible Steel Company, W. J. Ruby, Landis Machine Company, Francis White National Enameling & Stamping Company.

SCHENECTADY CHAPTER

The last meeting of the Schenectady Chapter was held May 25th in the Civil Engineering Building of Union College. The paper for this meeting was presented by Stanley P. Rockwell, consulting metallurgist of Hartford, Conn., entitled "Carburizing." Although carburizing is one of the older processes of treating steel, there are still many things to be learned

regarding it and Mr. Rockwell's paper described numerous new developments of the process. A lively discussion was held following this paper after which the election of officers took place.

LEHIGH VALLEY

The Lehigh Valley Chapter announces the following members that have been duly elected to office for the ensuing year:

Chairman, John E. Halbing, Ingersoll-Rand Company, Phillipsburg, N. J.; secretary-treasurer, Albert P. Spooner, Bethlehem Steel Company; executive committee, M. Laury, 256 Goepp street, Bethlehem, Pa., W. R. Shimer Bethlehem Steel Company, Bethlehem; G. C. Lilly, 707 West Market street, Bethlehem, F. P. Martin, 728 Reeder street, Easton, Pa., A. S. Hummel, 122 North Third street, Easton, Pa., R. Christ, 2023 West Broad street, Bethlehem, H. S. Brainerd, 121 Wayne avenue, Easton, E. B. Shimer, 94 Pennsylvania avenue, Easton, B. H. DeLong Carpenter Steel Company, Reading, Pa.

TRI CITY

The last meeting of the season of the Tri City Chapter was held June 1st in the rooms of the Davenport Chamber of Commerce. The meeting was opened by Chairman A. H. Putnam at which time the annual report of the secretary-treasurer was read and approved. The following members were unanimously elected to office for the ensuing year:

Chairman, J. F. Lardner, Jr., John Deere Plow Works, Moline, Ill.; vice chairman, L. S. Rasmusen, Linograph Company, Davenport, Iowa; secretary-treasurer Human Bornstein, 636 Tenth street, Moline, Ill. The executive committee consists of the newly elected officers and A. H. Putnam and C. H. Lage.

A motion was made and carried, in which the chapter extended a vote of thanks indicating their appreciation for the services of the out-going officers during the past year. After this meeting, A. H. Putnam, consulting metallurgist, presented a paper entitled "The Use of Various Tool Steels." This paper proved very instructive and aroused a great deal of interesting discussion. Mr. Putnam was given a vote of thanks after which the meeting adjourned.

WASHINGTON CHAPTER

At the May meeting of the Washington Chapter the following members were elected to office to serve for the ensuing year. They are:

H. J. French, chairman, Bureau of Standards; P. E. McKinney, vice-chairman, U. S. Naval Gun Factory; Jerome Strauss, secretary-treasurer, U. S. Navy Yard; executive committee, J. S. Vanick, 2034 F Street, N.W.; J. W. Talley, 1926 North New Hampshire Avenue, I. N. Beatty, 407 Evans Building, C. B. Scrimgeour, 410 Albee Building.

Commercial Items of Interest

MR. A. C. WEBSTER, a graduate of the School of Mechanical Engineering at Purdue University and whose reputation is international as a result of his efforts in the development of cold forging and cold heading of alloy and high carbon steel, has recently tendered his resignation as head of the cold heading plant of the Ford Motor Company at Highland Park, Michigan. The cold heading plant of the Ford Motor Company where millions of pieces are turned out daily is conspicuous among Ford units as a direct result of the efforts of Mr. Webster who has been superintendent of the plant for the last five years. Under his guidance the development of highly specialized tools and machines involving many labor saving devices is accredited to the cold heading department.

Mr. Webster is a member of the American Society for Steel Treating and is internationally known as a steel expert. He is now a practicing consulting mechanical and industrial engineer specializing in cold forging and cold heading. His office is at 903 West Euclid avenue, Detroit, Michigan.

Mr. F. J. Griffiths, General Manager of the Central Steel Company, Massillon, Ohio, has announced that two production records were broken during the month of May at the plants operated by his company. At the steel plant, more steel was produced during May than in any previous month in the plant's history, while the National Pressed Steel plant also had a greater production in May than in any previous month.

A recent scientific paper of the Bureau of Standards No. 433 by Wilmer Souder and Peter Hidnert deals with the thermal expansion of a few steels. Data on thermal expansion of 28 samples of iron and steel are included, one sample of vacuum electrolytic and one of gray cast iron are also included. A specimen of hardened steel has been tested to show the dimensional change incident to heat treatment or drawing. Twenty-two curves and a two-page table are used to summarize the results.

A brief review of some of the previous work on expansion is included.

The E. J. Codd Company, 700 South Caroline street, Baltimore, Maryland, have recently distributed several bulletins describing in detail the use of chain furnace doors. These bulletins are illustrated showing the actual application of numerous installations of chain doors of heating furnaces.

Wilson-Maeulen Company, Inc., New York City, has published a 20-page illustrated booklet in which pyrometers, pyrometer recorders, etc., are described and illustrated. A multirecord, multicolor pyrometer recorder is included in the equipment described. This operates with base metal or rare metal thermocouples in a thermoelectric pyrometer service. It also operates

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EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING, Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U. S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

ENGINEERING or PRODUCTION WORK—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired $200-$250. per month. Address 5-25.

SALESMAN—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

METALLURGIST—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired $4500. per year. Address 5-35.

SUPERVISOR HEAT TREATING—Or assistant. Ten years experience as chemist on iron and steel. One year practical experience on metallurgical inspection directly connected with heat treatment. Have made a study of the subject. No preference as to location. Wages $40.00 per week desired. Answer 5-50.

FURNACE DESIGNER and BUILDER—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

ASSISTANT METALLURGIST—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired $150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

METALLURGIST AND ENGINEER—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

CHEMIST—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

SALES ENGINEER—Thorough metallurgical training and experienced salesman. At present employed but desires change. Wide acquaintance New York, New England and Canada. Basic knowledge foreign markets and can produce. Age 28. Married. Address 4-5.

METALLURGIST OR CHEMIST—Graduate of Ohio State. Extensive experience covering heat treatment, case hardening, pyrometry, chemical analysis, metallography, and investigation of tool troubles. Best of recommendations. No preference as to location. Address: 4-50.

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

HEAT TREATING DEPARTMENT—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary $150.00. Cleveland location preferred. Address 4-10.

EMPLOYMENT SERVICE BUREAU

POSITION WANTED

SUPERINTENDENT OF HEAT TREATING—7 years experience heat treating of carbon, highspeed and other alloy steels. Experience in metallographic testing Understands pyrometry. Techincal education. Best of references. Location desired, Chicago or near vicinity. Address 6-15.

SERVICE MAN—for steel company. Experience in heat treatment of carbon, high speed and alloy steels, also metallographic testing and pyrometry. Technical education. Best references. Address 6-20.

SALES REPRESENTATIVE—At present holding responsible executive position. Desires to become representative of one or more manufacturing lines in excellent territory. Companies especially desiring representative for materials used in heat treating will find it to their advantage to correspond with No. 7-5.

CHEMIST AND METALLURGIST—thoroughly experienced in analysis of ferrous and nonferrous metals. Specialist in alloy steel analysis. Capable of taking charge of chemical and physical laboratory. Best of references. Age 30. Married. Salary commensurate with ability. Answer 7-20.

CHEMICAL AND METALLURGICAL ENGINEER with business education and 3 years practical consulting experience desires a position in laboratory or production departments. Address 7-30.

POSITIONS OPEN

WANTED—Young college graduate with one or two years practical experience in physical metallurgy to carry out physical tests and micro examination with a government bureau. Entrance salary $1800 per annum. Position offers excellent opportunity to become familiar with certain phases of physical metallurgy of great practical value. Address 4-32.

WANTED—Practical Superintendent for tool steet wire and shape drawing department. Reply box 6-5. care American Society for Steel Treating.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specialized in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-15.

FOR SALE

FOR SALE—Commercial Heat Treating Plant. Established business in good field. Excellent opportunity for young metallurgist to get into business for himself. Answer 7-10.

Leeds & Northrup, Hump Method, Electric Furnace for sale. Used very little. Address6-1.

FOR SALE—A ten-ton Gronwell-Dixon electric furnace with all accessories. This furnace is in excellent condition and is available at a very attractive figure. Address 7-25.

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as a low temperature recorder or electrical resistance thermometer in connection with resistance thermometer bulbs. Full details are given in the booklet, which also includes descriptions of parts, accessories, etc.

Alloys and alloy steel will be studied intensively by about sixty students in the department of mechanical engineering of the college of engineering of the University of Wisconsin. This subject is included in a new course in metallography. An increasing demand from factories and shops for men who know the heat-treatment of metals and alloys as well as understanding the properties of alloys has brought about the introduction of this new study.

The Burgess-Norton Manufacturing Company regrets to announce the suddent death, on Saturday, May 13, 1922 of their President Mr. Frank A. Burgess.

The Ithaca, N. Y., office of the Bureau of Mines is continuing the study of special series of molybdenum and cerium steels. Endurance tests with special regard to the effects of inclusions on endurance have recently been made. The final report on cerium has been made by Dr. H. W. Gillett to the Welsbach Company, which is the chief cerium producer and which cooperated in this work, being interested in finding new applications for this metal. A new shape of test bar has been adopted which seems better suited to endurance testing, and over two hundred test bars were prepared and sent out for machining. Metallographic study of inclusions and other causes of fatigue failure has been continued on bars prepared by the Bureau of Mines, and on some obtained from the University of Illinois and the United States Naval Experiment Station.

The Pittsburgh Testing Laboratory announces the opening of a sales office and inspection bureau at 1864 Railway Exchange Building, St. Louis, and the appointment of Col. N. C. Hoyles as district manager.

The Surface Combustion Company, New York, has issued a series of bulletins pertaining to industrial furnaces. One bulletin is devoted to surface combustion low-pressure air-gas inspirators, which are applicable to any gas furnace. A second bulletin is devoted to surface combustion oven furnaces and describes furnaces for the heat treatment of both carbon and high speed steel, etc. A third leaflet is devoted to surface combustion pot-hardening furnaces, a fourth to surface combustion soft metal furnaces ,a fifth to surface combustion galvanizing bath, a sixth to surface combustion shipyard furnaces, a seventh to surface combustion rivet heaters, an eighth to surface combustion small forges, and a ninth to surface combustion laboratory furnaces for high temperatures.

Experimental work on an investigation of the magnetic properties of a series of pure alloys of iron and carbon has recently been completed by the Bureau of Standards, Washington, D. C. A number of alloys were prepared having carbon contents ranging from 0.018 to 1.60 per cent and containing no impurities in sufficient amounts to be of importance. Normal induction and hysteresis data were obtained for magnetizing forces up to 2500 gilberts per centimeter and the results correlated not only with the carbon content but also with heat treatment. The reluctivity relationship previously used in a study of carbon steel with eutectoid composition was found to be useful in correlating the results. A paper describing the results of this investigation is in preparation.

The Firth-Sterling Steel Company of McKeesport, Pa., has opened a western office at 336 East Third street, Los Angeles, California. This office will be in charge of William E.Nelson, who has been engaged in marketing Firth-Sterling steel for twenty years. Mr. Nelson will be assisted by F. J. Kuhlman, L. W. Mead and T. D. Moore.

W. S. Rockwell Company, 50 Church street, New York City, has issued Bulletin No. 242, a supplement to the series of educational papers previously issued by this company and intended to illustrate the variety of methods of applying the principles of proper heating and handling to different manufacturing requirements and shop conditions. This bulletin covers the influence and method of heating on the quality and cost of heat-treated products.

Factory branches and offices have been opened at 222 West Larned street, Detroit, and at 2138 Oliver Building, Pittsburgh, by the Geo. Oldham & Son Company, Baltimore, pneumatic tools. The E. H. Welker Company, Inc., is the agent in charge at Detroit and J. A. Meredith is in charge at Pittsburgh.

The Mansfield Sheet & Tin Plate Company, and the Ohio Corrugating Company, D. B. Coey representative, have moved their sales offices to 910 South Michigan boulevard, Chicago, Room 1018.

M. K. Hitchcock, of the Ohio Refractories Company, Portsmouth, O., has acquired by purchase the Ironton, Ohio fire clay brick plant of the Basic Products Company.

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TRANSACTIONS
of the
American Society for Steel Treating

Vol. II Cleveland, August 1922 No. 11

THE BUSINESS SITUATION

THE apparent recovery of business in the United States has characterized the first half of 1922. Last year was not only a year of depression but was one of readjustment. The prosperity which followed the World War had come to an abrupt ending. Industrial and commercial concerns that had made large and easy profits during the war years, suddenly found themselves with large stocks of goods on hand which had diminished very decidedly in market value, and which could not be sold even at the lower prices to which they had been marked.

Under these conditions such concerns were slow in meeting their debts. Interest rates were climbing and with profits shrinking and in many cases disappearing, thousands of previously prosperous institutions were forced into insolvency. During the year 1921, commerce and industry slowed down to a point of business stagnation, financial loss and unemployment that have very seldom been equalled in similar periods in the country's history.

Periods of readjustment in the human relations of large numbers of people are slow and painful. There are few kinds of readjustment excepting those resulting from war, pestilence and famine which are as trying as that resulting from the downward readjustment in prices. Business slows down, industry diminishes and general hard times result.

During the first six months of this year we have had a general period of recovery. Interest rates have been falling and many companies that were in hard straights are beginning to see the light of day. Money is more readily obtainable and at easier rates, which augurs well for industrial and commecial expansion. Probably due to the slowed down activity in building during the period of war, a building boom is now in progress in the country and is of proportions which have never been equalled in our history. Continued progress in this direction will soon fill the building and housing shortage which accumulated during the war days and those following. It is reported that the banking situation of the country has been constantly improving until it now stands in a very good condition.

The bond markets have been very active and has provided millions of dollars in new capital for business in general. Prices to a large extent have stopped their downward trend and are now near enough in line with each other to permit a profit instead of a loss as has been the case in most industries.

Liberty bonds have been climbing in value until they now stand at par or better. The demand for rail and industrial stocks has risen

very decidedly and has placed considerable new capital in the hands of these interests to work with. In addition to the unprecedented building activity there have been two other cases of particularly significant industrial recovery. The first of these is the iron and steel industry, in which production has had an unprecedented period of improvement. The second is the automobile industry which has had a very decided business boom.

In summing up conditions it can be truly said that the first half of the year 1922 has been one of exceptionally vigorous recovery after the previous year of readjustment. There is every reason to believe that this condition will continue in spite of the fact that the rail and coal strikes are distressing the country at present. It is unlikely that these present handicaps will materially hinder the steady business improvement which the United States is now enjoying.

ALLEN-A-DALE OR SOCRATES

Sir Walter Scott masterfully portrayed in his Waverly novels the delectable and interesting characterists of the ancient Minstrels. No one was more forcibly presented than Allen-a-Dale, who journeyed from place to place and group to group singing his "merrie" lays to the great enjoyment if not of profit, of his many auditors. Entertainment was his fort and merriment reigned supreme wherever he pleased to wander and present himself.

Quite in contrast with the Scott character was the wise and gifted Socrates whose inspiring philosophy and interesting teachings made him a welcome guest and attracted to his sphere of influence those thirsting for a knowledge of the best things of life. Knowledge and inspiration, not levity, were his forte and consequently we recall with a less degree of effort, the teachings of Socrates than the lays of Allen-a-Dale.

Sales representatives have within their power the possibility of exercising characteristics and influences similar to the two types mentioned. There are many salesmen when making a call who feel it incumbent that they should divert themselves of sundry and so-called "stories" in an earnest endeavor to reach a common ground and understanding. Such representatives, while they may flatter and congratulate themselves upon the impression they believe they may have made, should wait until their next visit when the great possibility exists that they will warm the "mourner's bench" for an ungracious period or get the "too busy" signal.

If we admit there are too many salesmen of the Allen-a-Dale variety so must we readily consent to the proposition that there are too few of the "Socraterian" types. The salesman intelligently dispensing valuable information, such as the work of the research department of his organization has developed or his own knowledge and experience gathering facilities have accumulated, will always receive a cordial reception and unconsciously lay the foundations of confidence between user and producer, upon which, in the final analysis, the greatest portion of business is conducted.

Selling is an art as well as an honorable profession, and the success of some salesmen as contrasted to others, might well be the subject of analytical thought to determine if those characteristics and traits contributing to their advancement emulate the characteristics and traits of Allen-a-Dale or Socrates.

IT PAYS

No matter how altruistic our inclinations may be, stern necessity usually inquires, "Does it pay?" It is fortunate this constant check to our activities arises, otherwise we might disperse our earnings with a reckless abandon that would not augur well for the good of society in general. Experience has shown that there are some things that pay, such as savings accounts, careful investments, good health, efficient production and advertising. That it pays to advertise is a most generally accepted truth that has been decisively demonstrated. It is interesting to note that advertising pays dividends because whether it is direct mail, news, trade or society publication or exhibiting at expositions and conventions, it is the only means offered to the manufacturer to acquaint the possible user with his product.

While the man with a better mouse trap might have a path worn through the woods to his door, at the time of Emerson, it is doubtful if a light thus concealed under a basket would create any competition in this enlightened day. The recipient of a publication reads the advertisements with as great care as the short stories or technical articles. He has been educated to read the advertising section and no advertisement with a real message escapes his notice. The consumer realizes what a great obligation he owes to advertising mediums. It is to these he turns when in need because he realizes that a manufacturer who believes in his product so strongly that he is willing to tell the world about it undoubtedly has a product it would pay him to investigate. Advertising is not a one-sided dividend producer—it pays both the producer and the consumer.

RESEARCH AND ITS REWARD

Beyond all question of doubt the results obtained as the result of well directed research are most gratifying to the scientific world. The results observed and the data obtained form the basis of extended researches as well as forming a new or perhaps firmer foundation upon which the commercial world as well as the scientific world may base new theories or production. In this issue of the TRANSACTIONS a very interesting and commendable piece of research has been recorded. The author, S. C. Spalding, has made a real contribution to our knowledge of carburizing. It is regrettable that space did not permit of the exhibition of all of the photomicrographs which were obtained in the work, but those which are included show perhaps the penetration contrasts better than would have been the case if all of the photomicrographs had been reproduced. Mr. Spalding's metallurgical experience has been long and varied and his ability in conducting researches has been well demonstrated.

In this work the author has accomplished two important things. He has established additional accurate data to the art of carburizing steels and he has proven his ability as an experimenter. The reward therefore which accompanies well directed effort regardless of its nature is perhaps many fold. Chief among these rewards are the benefits which the world at large will derive from such effort and the gratification which the author will have in knowing he has rendered a real service to mankind.

HOTEL RESERVATIONS FOR DETROIT CONVENTION

Statler Hotel, Convention Headquarters

IN ORDER that all of our members and guests who will attend the fourth annual convention of the Society, may not be disappointed or inconvenienced in obtaining hotel accommodations, the following list of hotels, their rates and the number of guests they can accommodate are again being printed. Hotels in Detroit already are reporting heavy registration for the week of October 2nd. Thus it is important that members and guests who are planning to be present should write immediately to the various hotels in order to secure their reservations. The Statler Hotel will be the official headquarters but it is probable that it will not be possible for this hotel to accommodate all of our guests unless reservations are made immediately. All persons in attendance at the Detroit convention will make their own hotel reservation direct with the managers and it is advisable that the members take the following precaution: When making reservations, state that you are attending the International Steel Exposition and Convention of the American Society for Steel Treating, give the date of arrival, kind of room desired and the price you wish to pay. Request the hotel manager to answer your letter repeating the reservation, then take the letter with you to Detroit and present it when you register. This precaution taken now may avoid annoying difficulty during the rush of the Convention. It is recommended that reservations be made immediately.

The list of hotels follow:

Charlevoix Hotel

Rate With Bath
Single $3.00, $3.50, $4.00
Double $5.00, $6.00

Two-Room Suites.....$7.00
Three-Room Suites $8.25
Four-Room Suites $9.00

Number of persons with notice—100

Hotel Wolverine

Rate With Bath
Single $2.50, $3.00, $3.50, $4.00, $4.50, $5.00, $6.00
Double $4.50, $5.00, $5.50, $6.00, $6.50, $7.00, $8.00
Will accommodate 300

Hotel Norton

Rate Without Bath
Single $2.00 to $2.25
Double $4.00

Rate With Bath
Single $2.50 to $3.00
Double $4.50 to $5.50

Will accommodate 100

Lincoln Hotel

Rate Without Bath
Single $1.25, $1.50, $1.75, $2.00
Double $2.50, $3.00 (2 men)

Rate With Bath
Single 6 showers and tubs on each floor
Double no private baths

Will accommodate 75
Remarks: Large lobby. Good cafeteria.

Hotel Fort Shelby

Rate Without Bath	Rate With Bath
Single $2.00	Single $3.00, $3.50, $4.00, $5.00
Double $3.00	Double $5.00, $6.00, $7.00

Will accommodate 50 to 100

Cadillac Hotel

Rate Without Bath	Rate With Bath
Single 2.00, $2.50	Single $2.50, $3.00, $3.50, $4.00
Double $3.00, $3.50, $4.00	Double $4.00, $5.00, $6.00, $7.00

Will accommodate 500

Hotel Normandie

Rate Without Bath	Rate With Bath
Single $1.50 to $2.00	Single $2.50 to $3.00
Double $2.50 to $3.00	Double $3.50 to $4.00

Will accommodate 100

Madison-Lenox

Rate Without Bath	Rate With Bath
Single $2.00	Single $2.50, $3.00
Double $3.00	Double $3.50, $4.00

Will accommodate 100 or more

Library Park Hotel

Rate Without Bath	Rate With Bath
Single $1.25 to $2.00	Single $3.00
Double $2.00 to $3.00	Double $4.00

Will accommodate 50

Hotel Stevenson

Rate With Bath
Single $2.50
Double $3.50
Will accommodate 50

Hotel Statler

Rate With Shower	Rate With Bath
Single $3.00 to $3.50	Single $4.00 to $ 8.00
Double $5.00 to $5.50	Double $6.00 to $10.00

Will accommodate—400 rooms to take care of 600 to 800 people

Hotel Tuller

Rate With Bath
Single $2.50
Double $4.50
Will accommodate 300

Hotel Griswold

Rate Without Bath	Rate With Bath
Single $2.00	Single $2.50, $3.00, $3.50
Double $3.00	Double $4.00, $5.00, $6.00

Will accommodate 125

Hotel Addison

Rate Without Bath	Rate With Bath
Single $1.50	Single $2.50
Double $3.00	Double $4.00

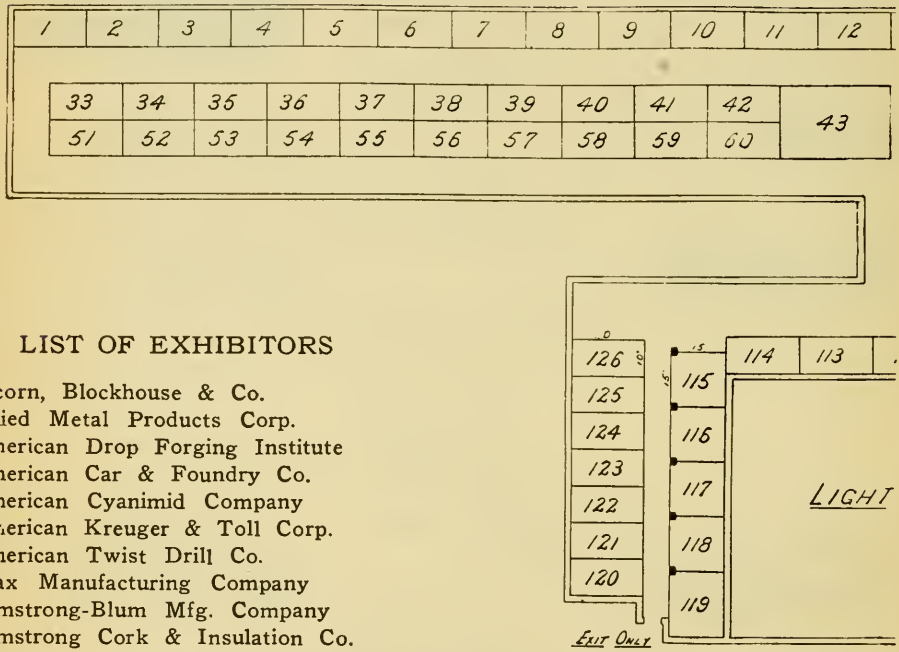
Will accommodate 250

EXHIBITORS AT THE INTERNATIONAL STEEL EXPOSITION

THE exhibition this year will be the most interesting and important the Society has ever held. There will be more exhibits in operation than ever before. Over 75 firms, as listed below, producing the highest class of products will be there to meet you and greet you, and not only to explain their products but to answer any questions you may have, and help you solve any difficulties in which you may be entangled.

A glance at the list of firms below will show that they represent the leaders, and they are anxious that you should examine their products.

FLOOR PLAN AND LIST OF EXHIBITORS GENERAL MOTORS BUILDING



LIST OF EXHIBITORS

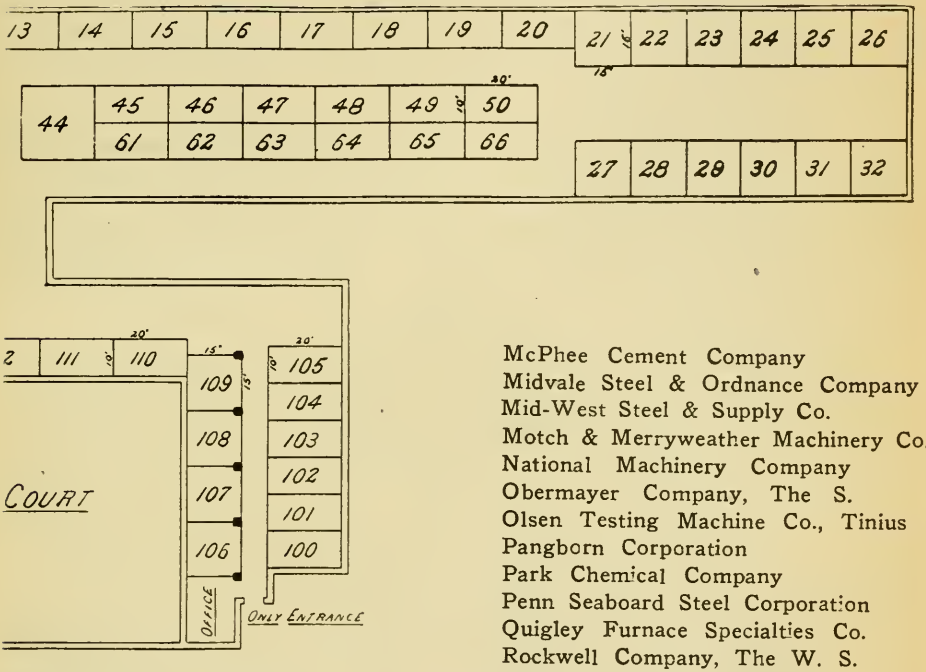
Alcorn, Blockhouse & Co.
Allied Metal Products Corp.
American Drop Forging Institute
American Car & Foundry Co.
American Cyanimid Company
American Kreuger & Toll Corp.
American Twist Drill Co.
Ajax Manufacturing Company
Armstrong-Blum Mfg. Company
Armstrong Cork & Insulation Co.
Bausch & Lomb Optical Company
Bellevue Industrial Furnace Co.
Blaich Company, The Alfred O.
Bristol Company
Brown Instrument Company
Bureau of Standards
Calorizing Company of Pittsburgh
Carborundum Company
Case Hardening Service Company
Celite Products Company
Central Steel Company
Climax Molybdenum Company
Colonial Steel Company
Crucible Steel Company of America
Dearborn Chemical Company
Driver-Harris Company
Electric Alloy Steel Company
Electro Alloys Company
Electric Furnace Co.
Engelhard, Inc., Chas.
Firth-Sterling Steel Company
Finkl & Sons, A.
Ford Company, The J. B.
Forging & Heat Treating
Ganschow Company, Wm.
General Alloys Company
General Electric Company
Hagan Company, The Geo. J.
Halcomb Steel Company

There is nothing that could be of greater value to you than to come to the Convention and Exhibition to examine at first hand the very latest in new equipment and products which should be used.

The list of exhibitors given below is not complete due to the fact that it was necessary to close the forms preparatory to going to press. The program distributed at the Convention will contain complete information.

Following is the exhibition hall floor plan and a partial list of exhibitors who will be present.

INTERNATIONAL STEEL EXPOSITION
DETROIT, MICHIGAN



Haynes-Stellite Company
Heppenstall Forge & Knife Co.
Holcroft & Company
Hoskins Manufacturing Company
Houghton & Company, The E. F.
Hoover Steel Ball Co.
International Nickel Company
Interstate Iron & Steel Company
Iron Age
Keller Mechanical Engraving Co.
Keystone Refractories
Kleist & Co., Chas.
Leeds & Northrup Company
Leitz, Inc., E.
Machinery

McPhee Cement Company
Midvale Steel & Ordnance Company
Mid-West Steel & Supply Co.
Motch & Merryweather Machinery Co.
National Machinery Company
Obermayer Company, The S.
Olsen Testing Machine Co., Tinius
Pangborn Corporation
Park Chemical Company
Penn Seaboard Steel Corporation
Quigley Furnace Specialties Co.
Rockwell Company, The W. S.
Rodman Chemical Company
Shore Instrument & Mfg. Co.
Simonds Steel Company
Spencer Turbine Company
Standard Alloys Company
Standard Fuel & Engineering Co.
Surface Combustion Company
Taylor Instrument Company
Taylor Company, The N. & G.
United Alloy Steel Company
Vanadium-Alloys Steel Company
Vanadium Corporation of America
Westinghouse Electric & Mfg. Co.
Wilson-Maeulen Company
Witherow Steel Company

A COMPARISON OF THE RATE OF PENETRATION OF CARBON INTO VARIOUS COMMERCIAL STEELS IN USE FOR CASE CARBURIZING

By S. C. Spalding

THE changing of iron or low carbon soft steel into high carbon steel possessing extreme hardness after quenching, by a process which does not require the fusion of the metal, is an art that has been in practice for many hundreds of years. In the olden days, the individual who accidentally or otherwise discovered a method of case hardening, guarded his secret jealously, therefore the art was practiced long before any evidence of it was set down in writing. A certain smith would be known to have some wonderful method of producing superior tools from ordinary iron but his work would be shrouded in great mystery, only to be performed in certain favorable phases of the moon, and such occult foolery. Such methods used by the first man for concealment were passed on as an essential part of the process thus obscuring its true principles.

The earliest written evidence of the use of this cementation or carburizing process is found in the writings of Vannuccio Biringuccio, published in 1540 under the title of "Pirotechnia" and in the treatise "De re Metallica" by George Agricola, published in 1556. Both of the above authorities describe a method of heating soft iron billets in a bath of molten cast iron from which they absorbed carbon and became capable of taking on a hard surface. The early uses of the carburizing process seem to have been for the production of a superficial hardening on finished articles of soft iron similar to our modern case hardening.

Beginning in the seventeenth century the process began to be applied to carburizing completely whole bars or billets of iron transforming them into steel, which were subsequently forged into finished shapes. At this time this was the only method for the production of steel, and its discovery led to a wide increase in the use of the cementation process in which case hardening became only a minor issue. The discovery of the crucible process in 1740 by Huntsman, in which steel produced from iron by cementation was used as the raw material, gave greater impetus to cementation or carburizing. These conditions continued until the invention of puddled steel in 1830, followed shortly by the Bessemer process and the open-hearth process which practically did away with the manufacture of steel by total cementation and the carburizing process reverted to its original purpose, the production of surface hardness on finished soft steel parts. In this field carburizing still finds extensive use. At the present time many special steels are made which are adapted to the production of finished parts with a hard wearing surface encasing a soft tough core. It is with this phase, the modern case carburizing process, that the data in this paper is concerned.

Purpose of Investigation

Many investigators have worked on the problem of the effect of carburizing agents on steels, but the problem is always rendered more complex by the introduction of new steels suited or said to be suited to the process, until the present day users have a large number of steels from which they must select the one best suited to their needs with no exact data on which to base

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A paper presented at the Indianapolis Convention of the Society. The author, S. C. Spalding is metallurgist, Halcomb Steel Co., Syracuse, N. Y.

their selection. The most complete and exhaustive treatise on the subject at present available, is Dr. Giolitti's work "The Cementation of Iron and Steel." In this work there is collected, summarized and discussed all of the work which had been done by other investigators up to the time of its publication, 1912. Lothrop, in his paper entitled "Case Carbonizing," published in the *Transactions* of the American Society of Mechanical Engineers, 1912 gives much valuable data on plain carbon, nickel and chromium vanadium steels. A number of articles have appeared in the TRANSACTIONS of the American Society for Steel Treating, but have dealt mostly with furnaces, methods, costs, etc., rather than comparing the rates of penetration of different steels. The apparent lack of comparative information on the rate of penetration under identical conditions of different commercial carburizing steels, led to the securing of the data which is here published, with the hope that they may make a valuable addition to the information available to the user of case carburizing steels.

The steels investigated comprise a plain carbon cold rolled steel, a plain carbon hot rolled steel, a chromium silico-manganese steel, a chromium-vanadium steel, a 3½ per cent nickel steel, a 5 per cent nickel steel, two types of chromium nickel steel and a chromium molybdenum steel. The material from which the specimens were made was in the form of 1 inch round bars. The test pieces were cylinders ¾ of an inch round by 2 inches long. One piece from each bar was packed in a cylindrical pot as shown in Fig. 1.

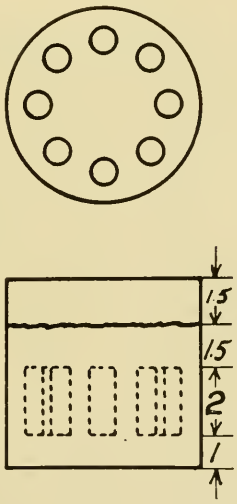


Fig. 1 Arrangement of test pieces in carburizing box for carburizing penetration investigation.

The carburizing agent was a standard commercial compound. The boxes were made of sections cut off pipe with a bottom welded in one end. A circular plate fitting inside the top was used as a cover, this cover being luted on with fire clay. Sixteen boxes were loaded into a large oil-fired heating furnace having a hearth 6 feet wide and 20 feet long heated by five oil burners and equipped with pyrometers so that all parts of the furnace could be kept at a uniform temperature. The boxes were brought up to temperature and the period of carburizing computed from that time. After five

hours at temperature, two boxes were pulled out. At the next time interval of five hours two more were pulled out, etc. This gave duplicate specimens for each period of time, each from a different box. When the boxes had cooled down the cylinders were taken out, the end cut off, then slit in two longitudinally as shown in Fig. 2. The depth of case was read with the aid of the microscope, measuring in from the end surface until a point was reached where the carbon had fallen to approximately 50 per cent.

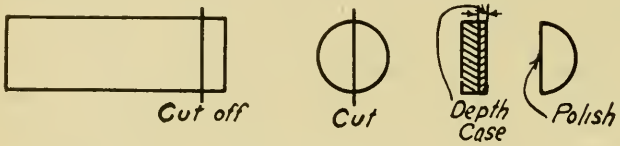


Fig. 2 Method of cutting specimens for microscopic examination.

Two runs were made, one at 1600 degrees Fahr. and one at 1700 degrees Fahr., with time periods at 5, 10, 15, 20, 25, 30, 40 and 50 hours. To check up some irregularities an additional run was made at 1700 degrees Fahr., with time periods of 20, 22½, 25, 27½, 30, 40, 50 and 55 hours. In each of the 1700 degree Fahr. runs a large oil-fired furnace was used and all the boxes were loaded in at the start and pulled out as their time came. In the 1600 degree Fahr. run it was not possible to have the use of this furnace and a smaller oil-fired furnace was used in which only four boxes could be loaded at a time. The 5 and 10 hour runs were made together, then the 15 and 20, etc.

The chromium molybdenum data were obtained in a separate run by packing two specimens of the chromium molybdenum steel with a specimen of the chromium vanadium steel in the same box, using the same large furnace, the same method of pulling the boxes, etc. The chromium vanadium steel, on which we already had data, gave a base with which to compare the chromium molybdenum steel with the other steels. The chemical composition of the steels used in this investigation are shown in Table I.

A complete microscopic examination was made of every specimen together with photomicrographs taken at 50 and 250 magnifications showing the case at each temperature and time period. A photomicrograph of each original bar was also taken, using a magnification of 500. Curves of the 1600 degree Fahr. and 1700 degree Fahr. runs were plotted for each steel on composite charts for the purpose of rapid comparison, as shown in Fig. 3 and Fig. 4.

Discussion of Results Shown in Curves

The steels may be divided into five general classes:

1. *Straight Carbon Steels.*

The curves for these two steels are seen to be identical in shape. If one be plotted over the top of the other they are practically coincident throughout their length. The cold rolled steel is, however, considerably lower than the other. Some authorities claim that cold rolling of steel reduces its power to absorb carbon. To writer's mind, however, the principal reason for the difference in rate of penetration on these two steels may be ascribed to the increased phosphorus and sulphur content of the cold rolled stock.

2. *Chromium Silico-Manganese Steels.*

In this group may be included the chromium silico-manganese and the

chromium vanadium steels. The chemical analysis of these two steels differs only in the 0.17 per cent vanadium content of the chromium vanadium steel. The curves for these two steels are coincident up to 40 hours. From 40 to 55 hours there is a very slight difference in favor of the chromium silico-manganese. These results indicate the 0.17 per cent vanadium to be without influence on penetration of carbon.

3. *Nickel Steels.*

Nickel, an element which goes into solid solution with the iron, retards penetration of carbon. This hypothesis is borne out by the data. The curve for the five per cent nickel steel lying considerably below that for the 3½ per cent nickel steel.

4. *Chromium Nickel Steels.*

The curves for these steels indicate the beneficial effects of chromium combined with nickel in aiding the penetration of carbon. The higher type 1 50 per cent chromium, 3.50 per cent nickel curve lies above the 1.00 per cent chromium 3.00 per cent nickel.

5. *Chromium Molybdenum Steel.*

The curve for this steel is in shape more like the chromium vanadium steel. It lies, however, considerably above, illustrating the helpful effect of molybdenum on the absorption of carbon.

Comparing groups 1 and 2, we notice the chromium silico-manganese

Table I

Chemical Analysis of Steels Under Investigation

Type of Steel	C	Mn	P	S	Si	Cr	Ni	Va	Mo
Carbon Cold Rolled	0.15	0.72	0.103	0.092	0.015	...	...	...	...
Carbon Hot Rolled	0.20	0.54	0.007	0.031	0.020	...	...	...	...
Chromium Silico-Manganese	0.16	0.78	....	0.019	0.31	0 83	...	...	...
Chromium Vanadium	0.17	0.73	0.010	0.020	0 33	0.92	...	0.17	...
Nickel Steels	0.16	0.65	0 013	0.019	0.15	...	3.50	...	...
	0.14	0.38	0.008	....	0.095	...	5.29	...	...
Chromium Nickel	0.18	0.60	0.012	0.009	0.30	0.98	3 14	...	...
	0.11	0.40	0 018	0 011	0 16	1.31	3.79	...	...
Chromium Molybdenum	0.13	0.38	0.009	0.010	0.21	0.96	...	...	0.48

steels give deeper penetration than the straight carbon steels. This difference is no doubt due mainly to the presence of 1 per cent chromium. Looking at group 3 we see that the rate of penetration for 3½ per cent nickel steel is greater than the straight carbon and naerly as great as the chromium silico-manganese steels. The reason for this is that although nickel has a retardent action on carbon penetration, the critical temperatures for nickel steel are 100 degrees Fahr. lower. At 1700 degrees Fahr. nickel steel is therefore at a higher heat above its critical point. We should more properly compare the 1600 degree Fahr. runs for nickel with the 1700 degree Fahr. for the others. The curves for the chrome nickel steels are considerably higher than any of the others excepting the chromium molybdenum steel.

Inasmuch as the chromium vanadium of group 2 and the 1.00 per cent chromium 3.00 per cent nickel of group 4 differ only in the presence of nickel in the group 4 steel, it seems that nickel in the presence of chromium has a beneficial effect on carbon penetration, greater than chromium alone.

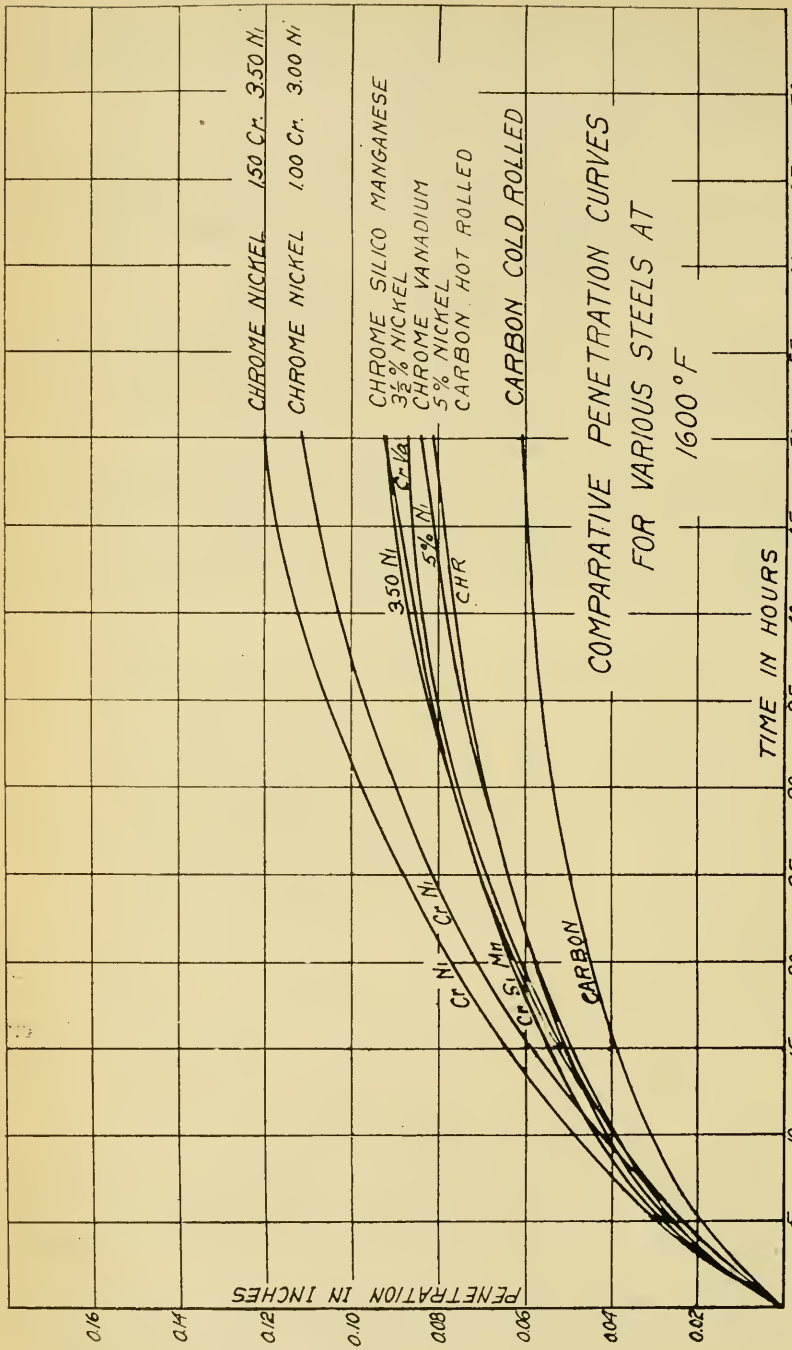


Fig. 3 Comparative carbon penetration curves for various steels subjected to a temperature of 1600 degrees Fahr.

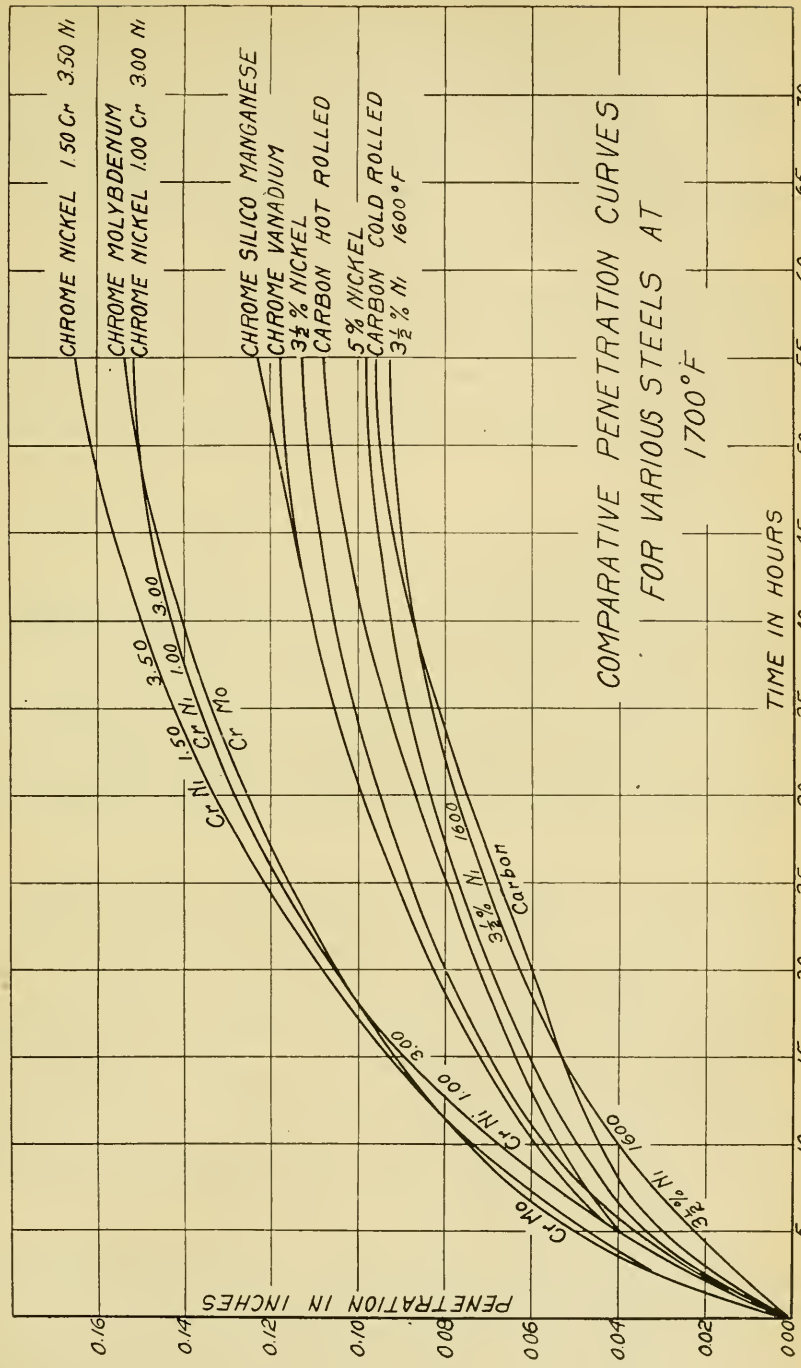


Fig. 4 Comparative carbon penetration curves for various steels subjected to a temperature of 1700 degrees Fahr.

Microstructure

A complete series of photomicrographs were made of the original bar of each steel and the case after each time-temperature period. Inclusions of all the photos in this paper would make it very voluminous and not add greatly to its usefulness. Due to the fact that space does not permit of the reproduction of all of the photomicrographs which were made during this investigation the writer has selected one photomicrograph of the bar as received and two each of the 5, 25 and 50 hour periods at 1600 and 1700 degrees Fahr. These photomicrographs are shown in Figs. 5 to 136 inclusive.

Group 1 Straight Carbon Steels

Considering just the straight carbon cold rolled steel, we notice that it is an impure steel high in phosphorus and sulphur. This is borne out by the numerous slag and sulphide inclusions showing in the original bar and in the case and core of the different specimens. After 5 hours at 1600 degrees Fahr. the case produced is comparatively thin being between 1/64th and 1/32nd of an inch deep and mainly eutectoid in character, made up of pearlite grains. There is a thin area of cementite network structure present at the outer surface.

Twenty five hours at 1600 degrees Fahr. produces a case in the neighborhood of 3/64ths of an inch in thickness, mainly eutectoid, with a slight layer of free cementite at the edge in netword areas.

Fifty hours at 1600 degrees Fahr. produces approximately a 1/16th inch case. Here the cementite network in the outer zone is more pronounced.

At 1700 degrees Fahr. a case of an entirely different character is produced. Near the outer surface a hyper-eutectoid zone is formed, made up of coarse cementite network structure surrounding pearlite grains. This is followed by a eutectoid and hypo-eutectoid zone similar to the 1600 degree Fahr. run. The zone of excess cementite is relatively light, not over 0.008 to 0.010 inches in depth and could be ground off the finished part leaving a deeper eutectoid case than is obtained after 5 hours at 1600 degrees Fahr.

After 25 hours at 1700 degrees Fahr. we greatly increase the depth of the zone containing free cementite network which covers a deep eutectoid and hypo-eutectoid zone. At 50 hours we have produced a very deep case of approximately 3/32 inch but, at the same time greatly increasing the depth of the area of cementite network. One specimen not shown in photomicrographs, was run for 24 hours at 1700 degrees Fahr. The effect of slag and nonmetallic impurities in breaking up the continuity and uniformity of the case was clearly observed. Near the center a streak of segregated impurities was observed to run out to the surface of the metal. This area resisted the penetration of carbon and caused a soft spot at that point. The effect of the higher heat was to produce a deeper case, but one containing a deeper and more coarse cementite network structure. Figs. 13 to 28 inclusive illustrates the structures observed in the cold rolled steels as carburized and as carburized and quenched.

The structure of the original bar of straight carbon hot rolled steel, Fig. 6, is seen to be ferrite and pearlite with absence of the slag and sulphide areas which were present in the impure cold rolled steel.

Figs. 29 to 44 show the microstructures observed after the carburizing tests of the hot rolled steel. Five hours at 1600 degrees Fahr. is seen to give a case a little better than 1/32 inch in depth, with a rather thin zone of cementite network. Comparison with the cold rolled steel shows the much

deeper case which is obtained on this steel in the same time at temperature. Twenty five hours at 1600 degrees Fahr. produces a deeper case with a deeper hyper-eutectoid layer. In 50 hours we have produced a 5/64ths inch case made up of distinct hyper-eutectoid, eutectoid and hypo-eutectoid zones. At 1700 degrees Fahr. the case increases in depth and the cementite network areas become thicker and the grains larger.

We see that in the plain carbon steels the case produced is characterized by an outer layer of coarse cementite network structure, followed by an eutectoid and hypo-eutectoid zone, the depth and coarseness of structure being a function of time and temperature. In treating carburized parts frequently they are cooled in the box as were these specimens, then subjected to a single reheat and quenched to refine and harden the case. When a coarse cementite network structure is present a single low heat will not break it up and we will have a brittle spalling case. It is necessary for refinement to first quench from a high enough heat to take the cementite into solution then refine the grain by a second low quench. The photomicrographs show that the alloy steel under the same conditions take a structure which may be more easily refined. We will now pass to the first of the so-called alloy steels.

Group 2, Chromium Silicon Manganese and Chromium Vanadium Steels.

Examination of the photomicrographs of this group Figs. 45 to 76 inclusive shows the structures to be of a different character than the straight carbon steels. The enormous pearlite grains of the latter group are now absent. Carburizing at heats up to 1700 degrees Fahr. has little effect on the grain size. The cementite network structure is absent and we find the excess carbides occurring as globules uniformly distributed through the hyper-eutectoid zone. The penetration of carbon at the same time is much greater. Comparing the chromium silicon manganese and the chromium vanadium steels we see that the vanadium, although not affecting the rate of penetration, has a beneficial effect in producing a denser, more finely divided structure.

Group 3. Nickel Steels

In the 3½ per cent nickel steel, photomicrographs of which are shown in Figs. 77 to 92 inclusive we find the excess carbide occurring as small globules and a fine network surrounding the grains. At 1700 degrees Fahr. the structure appears to be somewhat coarsened but not badly overheated. The 5 per cent nickel steels, photomicrographs of which are shown in Figs. 93 to 108 inclusive are approaching the air hardening range of steels. In the high carbon zone the structure is made up of coarse martensite with patches of austenite. As the carbon gets lower we pass into troostite, sorbite and pearlite. No network structure is found, and what carbide is visible appears to be distributed as small globules.

Group 4. Chromium Nickel Steel

In the case of the chromium nickel steel, when the carbon content is raised by carburizing, it becomes air hardening. The structures as cooled in the boxes, show austenite and martensite passing to troostite, sorbite and pearlite as we approach the core. Photomicrographs of this series is shown in Figs. 109 to 126 inclusive. At the very edge there appears a layer of excess carbides mostly as globules, as though the steel had absorbed the carbon more rapidly than it could diffuse it and take it into solution. This steel

has a strong tendency toward a streaky structure and this tendency of the bar is carried into the case where it is necessary to eliminate it by proper heat treatment.

Group 5. Chromium Molybdenum Steel

The carburized zones in this steel, shown in Figs. 127 to 136 inclusive, are more on the order of the chromium silico-manganese steel. The cementite in the hyper-eutectoid zones occurs as large globules as in the chromium silico-manganese steel, but there is also considerably more of the large network structure present than in any of the other alloy steels. In this respect this steel approaches the straight carbon steel structures.

Effect of Heat Treatment

The heat treatments which were used were taken from S.A.E.Recommended Practice and were applied to specimens which were carburized for the 50-hour run at 1700 degrees Fahr.

Group 1—Straight Carbon Steel.

Single treatment—Heat to 1475 degrees Fahr. quench in water.

Double treatment—Heat to 1585 degrees Fahr. quench in oil; reheat 1425 degrees Fahr., quench in water.

The effect of the double treatment as compared to the single is seen to be in much greater core refinement, Figs. 25, 26, 27, 28, 41, 42, 43 and 44, and in causing some diffusion and solution of the outer cementite network.

Group 2—Chromium Silico-Manganese and Chromium Vanadium Steels.

Single treatment CrSM 1475 degrees Fahr., quench in water.

Single treatment Cr Va. 1525 degrees Fahr., quench in water.

Double treatment CrSM 1585 degrees Fahr., quench in oil: reheat to 1425 degrees Fahr., quench in water.

Double treatment Cr Va. 1675 degrees Fahr., quench in oil: reheat to 1475 degrees Fahr., quench in water.

Figs. 57, 58, 59, 60, 73, 74, 75 and 76 show photomicrographs of these steels revealing greater refinement of case and core with single treatment than do the straight carbon steels. The chromium vanadium steel shows a more dense uniform case. The thickness of the excess carbide zone is greater but there is complete absence of any network.

Group 3—Nickel Steels—3½ Per Cent and 5 Per Cent

Single treatment—3½ per cent Nickel heat to 1475 degrees Fahr., quench in water.

Double treatment—3½ per cent Nickel heat to 1525 degrees Fahr., quench in oil. Reheat to 1350 degrees Fahr., quench in water.

Single treatment—5 per cent Nickel heat to 1475 degrees Fahr., quench

Single treatment—5 per cent Nickel heat to 1475 degrees Fahr., quench

Double treatment—5 per cent Nickel heat to 1500 degrees Fahr., quench in oil. Reheat to 1300 degrees Fahr., quench in water.

The case and core of both these steels appear absolutely uniform after either single or double treatment as shown in Figs. 89, 90, 91, 92, 105,

106, 107 and 108. No trace of excess cementite as in the other steel is visible here. The double treatment gives a more refined core and case than the single treatment.

Group 4—Chromium Nickel Steel.

Single treatment—heat to 1500 degrees Fahr., quench in oil.

Double treatment—heat to 1600 degrees Fahr., quench in oil; reheat 1425 degrees Fahr., quench in oil.

This steel shows a dense fine grained core and case after either treatment as shown in Figs. 123, 124, 125 and 126. The structure after double treatment however, appears somewhat more refined and uniform. Some of the excess carbide is visible at the edge but there is an entire absence of network structures.

Group 5—Chromium Molybdenum Steel

Single treatment—heat to 1500 degrees Fahr., quench in water.

Double treatment—Heat to 1600 degrees Fahr., quench in oil; reheat to 1475 degrees Fahr., quench in water.

This steel does not lend itself to refinement of case by either single or double treatment. The core apparently becomes well refined by either. The case is better after double treatment but in either condition has altogether too much of the network structure. This would make a very brittle part. The photomicrographs of this type of steel is shown in Figs. 133 to 136 inclusive.

Conclusions

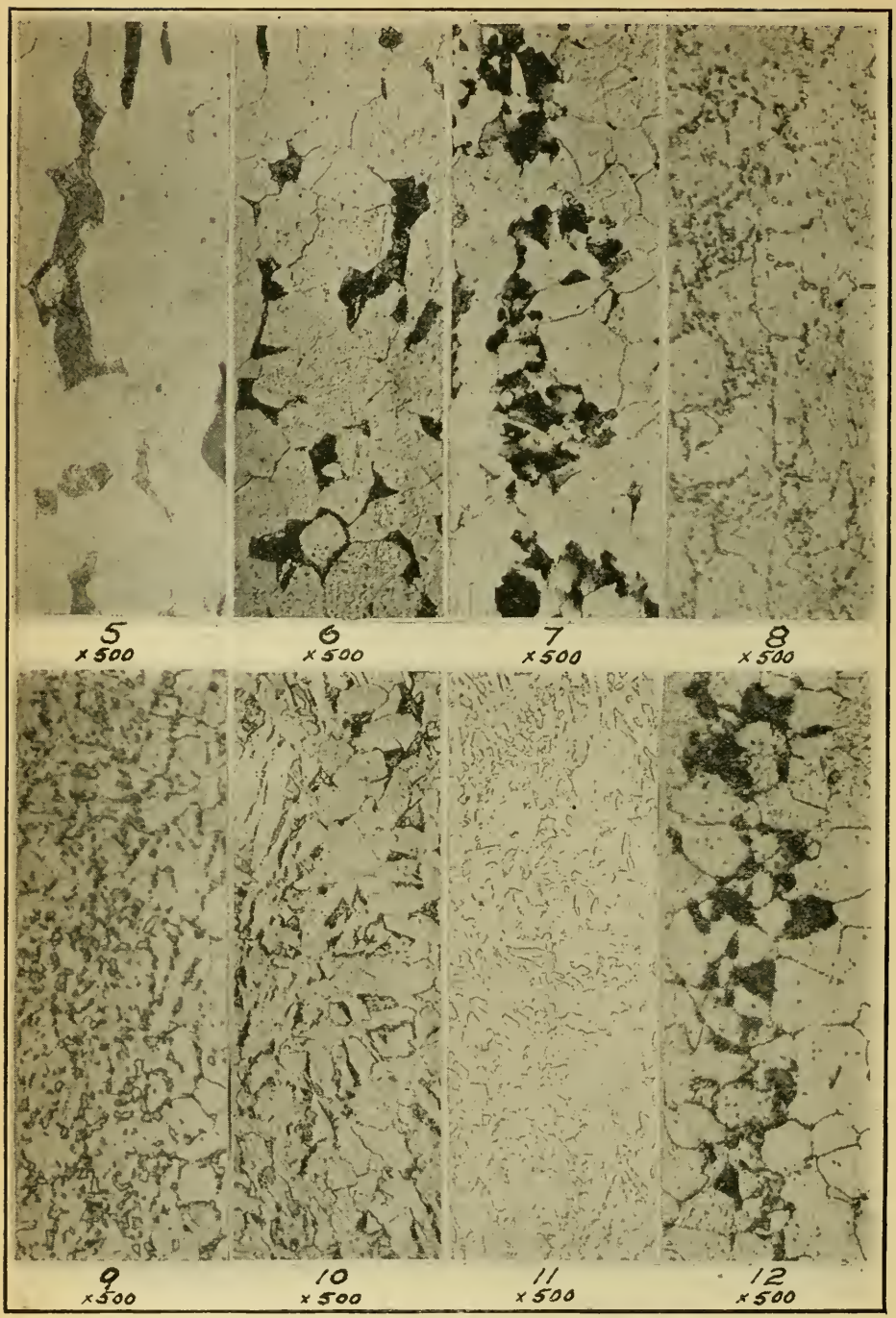
In summing up, the writer wishes to say that the work that has been done in this investigation indicates the superiority of the Chromium Nickel and Chromium Molybdenum steels insofar as rate of penetration of carbon is concerned. The Chromium Vanadium and Chromium Silico-Manganese steels come next, then the Straight Carbon steels, with the Nickel steels last.

This would indicate Nickel to be a retarding agent when present alone but a helping agent when present with Chromium. The difference between the cold rolled and hot rolled Straight Carbon steels shows the retarding effects of high phosphorus and sulphur. We find Vanadium in percentages of 0.17 to be of no effect on rate of penetration of carbon.

From the standpoint of microstructure the work indicates the superiority of the alloy steels over the Straight Carbon steels. They are more easily refined by single treatment and much superior after double treatment. Chromium Molybdenum steel appears to be an exception to this in that its case is not readily refined by either single or double heat treatment; in fact a good grade of carbon steel seems preferable.

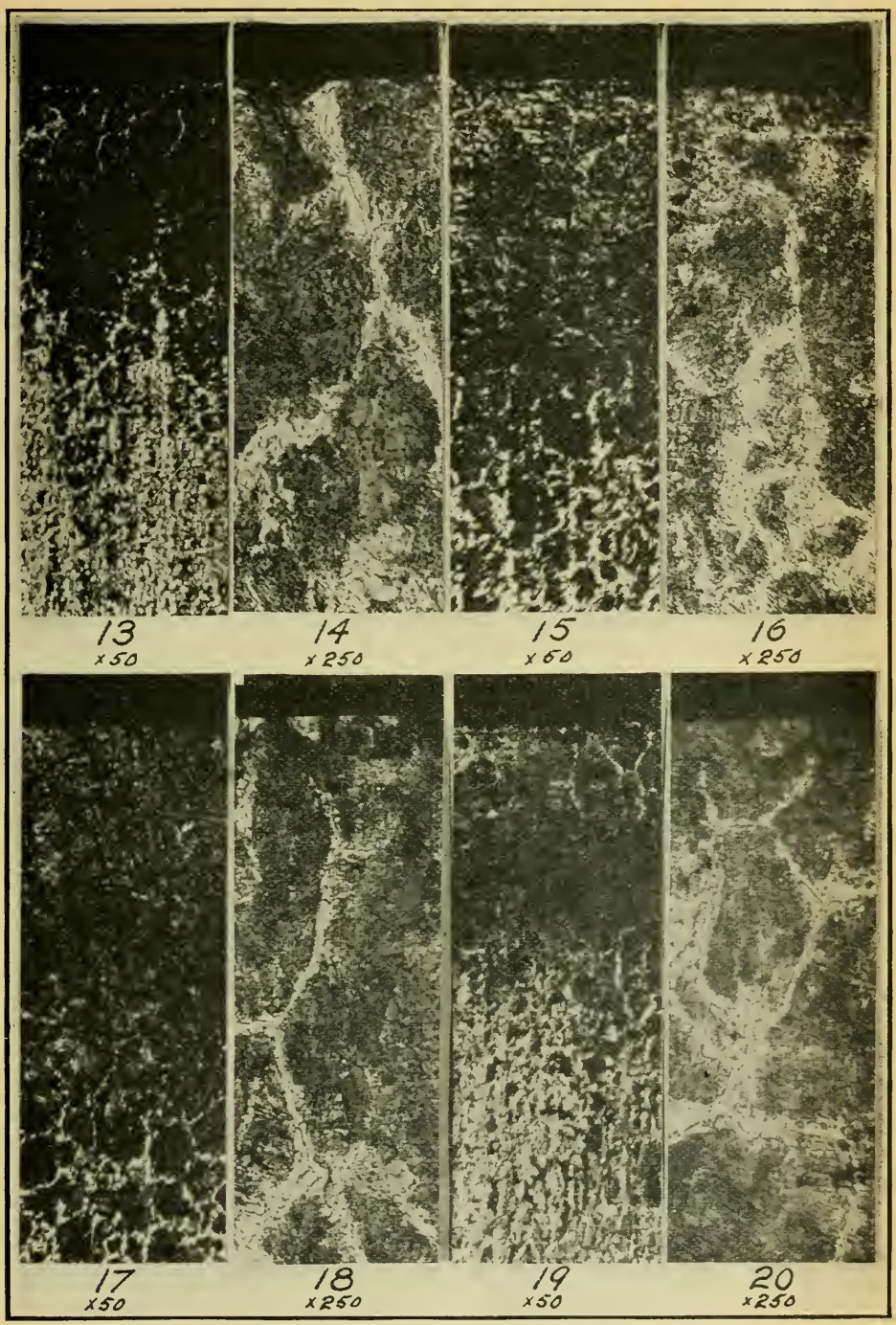
In selecting a steel for case hardening, therefore, it is very evident that many factors must be considered. The writer sincerely hopes that the research work he has done as evidenced by the data included in this paper may serve as a guide as to what is to be expected in the way of the rate of carbon penetration in the commercial steels.

The photomicrographs obtained in this research follow on pages 960 to 976 inclusive.



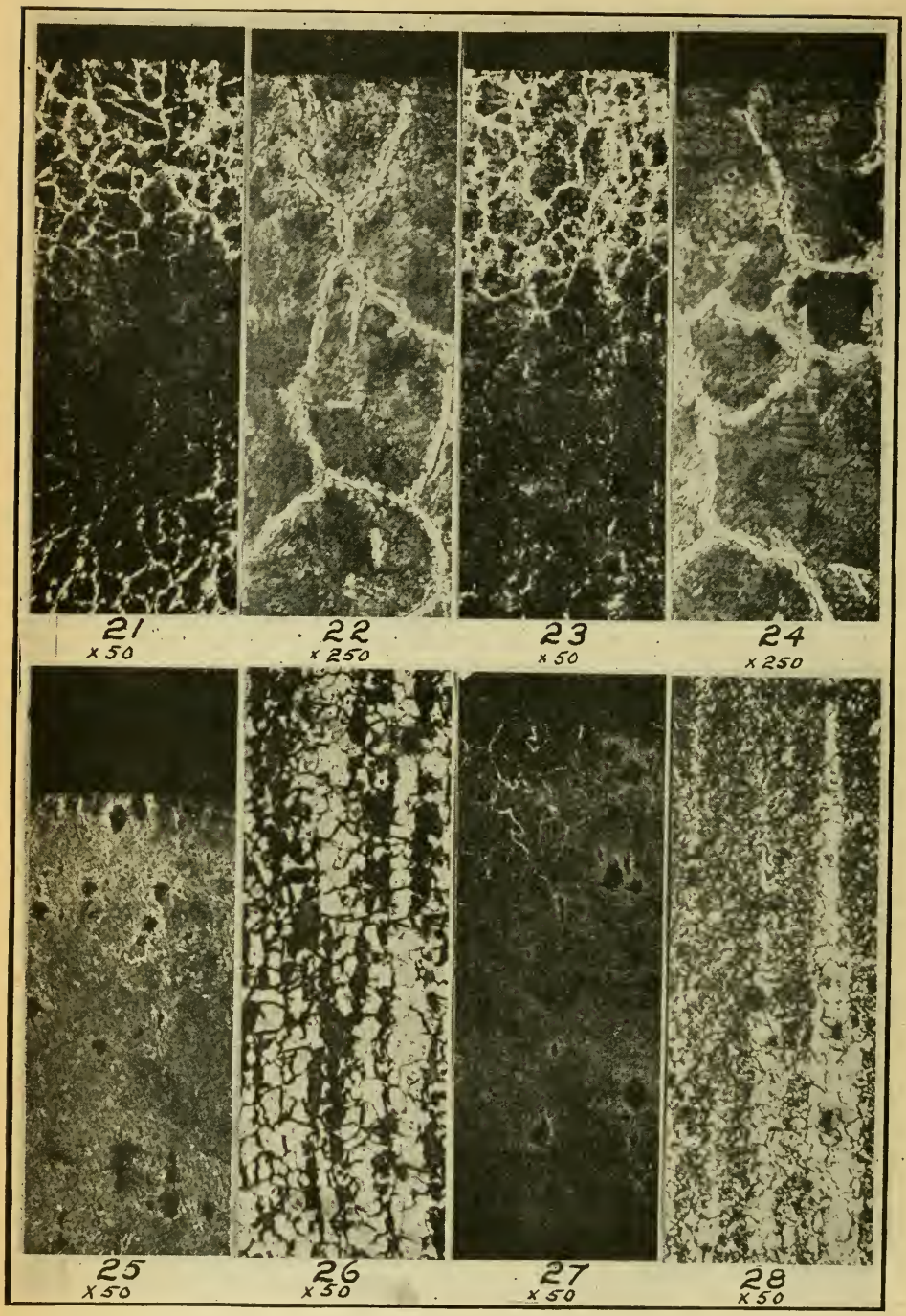
ORIGINAL BAR STEEL STRUCTURE AS RECEIVED

Fig. 5 Cold Rolled Steel Showing the Presence of Non-metallic Inclusions Fig. 6 Hot Rolled Steel. Fig. 7 Chromium Silicon Manganese Steel. Fig. 8 Chromium Vanadium Steel. Fig. 9 Three and one half Per cent Nickel Steel. Fig. 10 Five Per cent Nickel Steel. Fig. 11 Chromium Nickel Steel. Fig. 12 Chromium Molybdenum Steel.



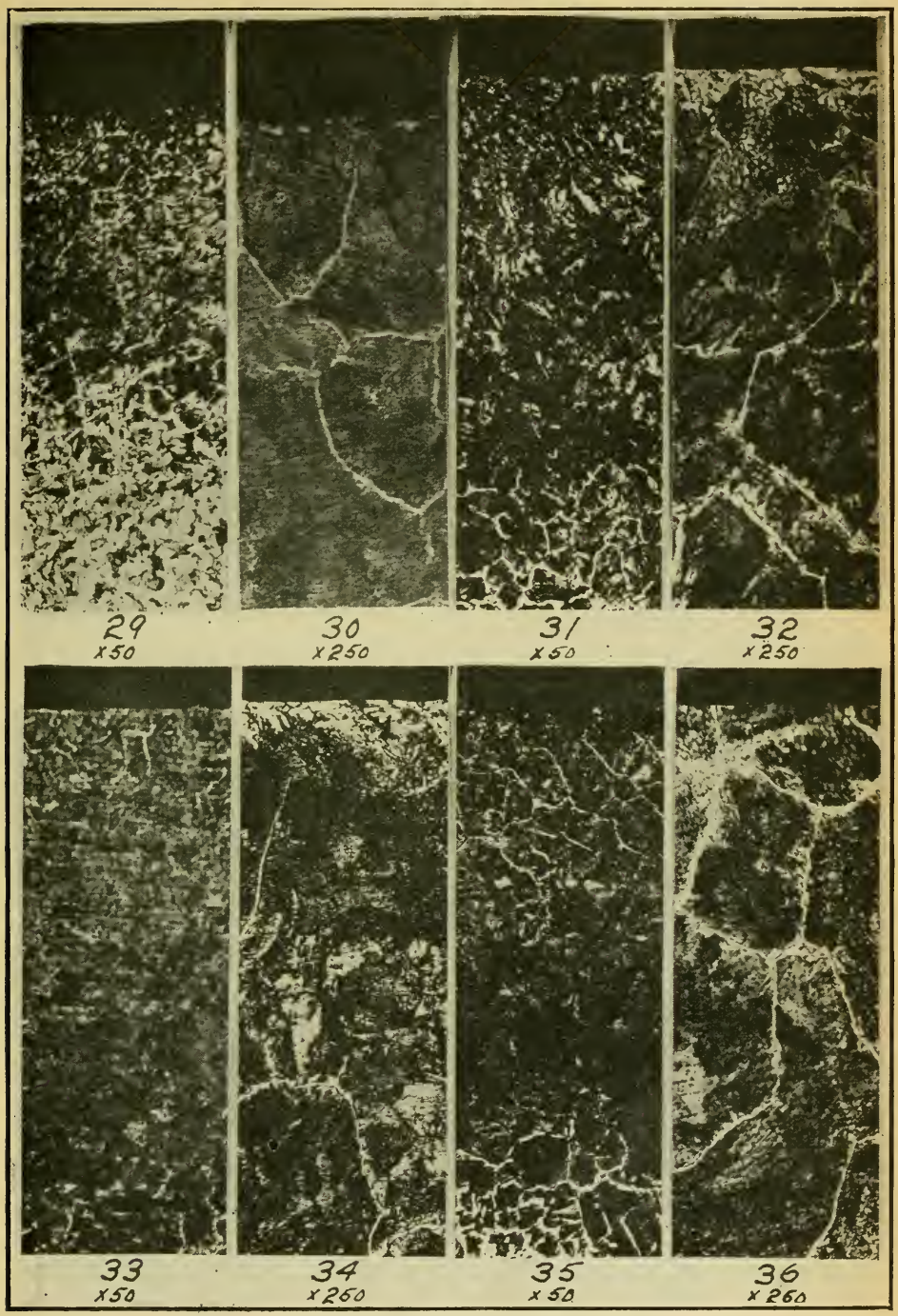
COLD ROLLED CARBON STEEL

Figs. 13 and 14, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 15 and 16, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 17 and 18, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. It will be noticed that the case in each specimen is mainly eutectoid in character with a slight cementite network near the outer surface. About 1/16 inch case was obtained after 25 hours. Figs. 19 and 20, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr.



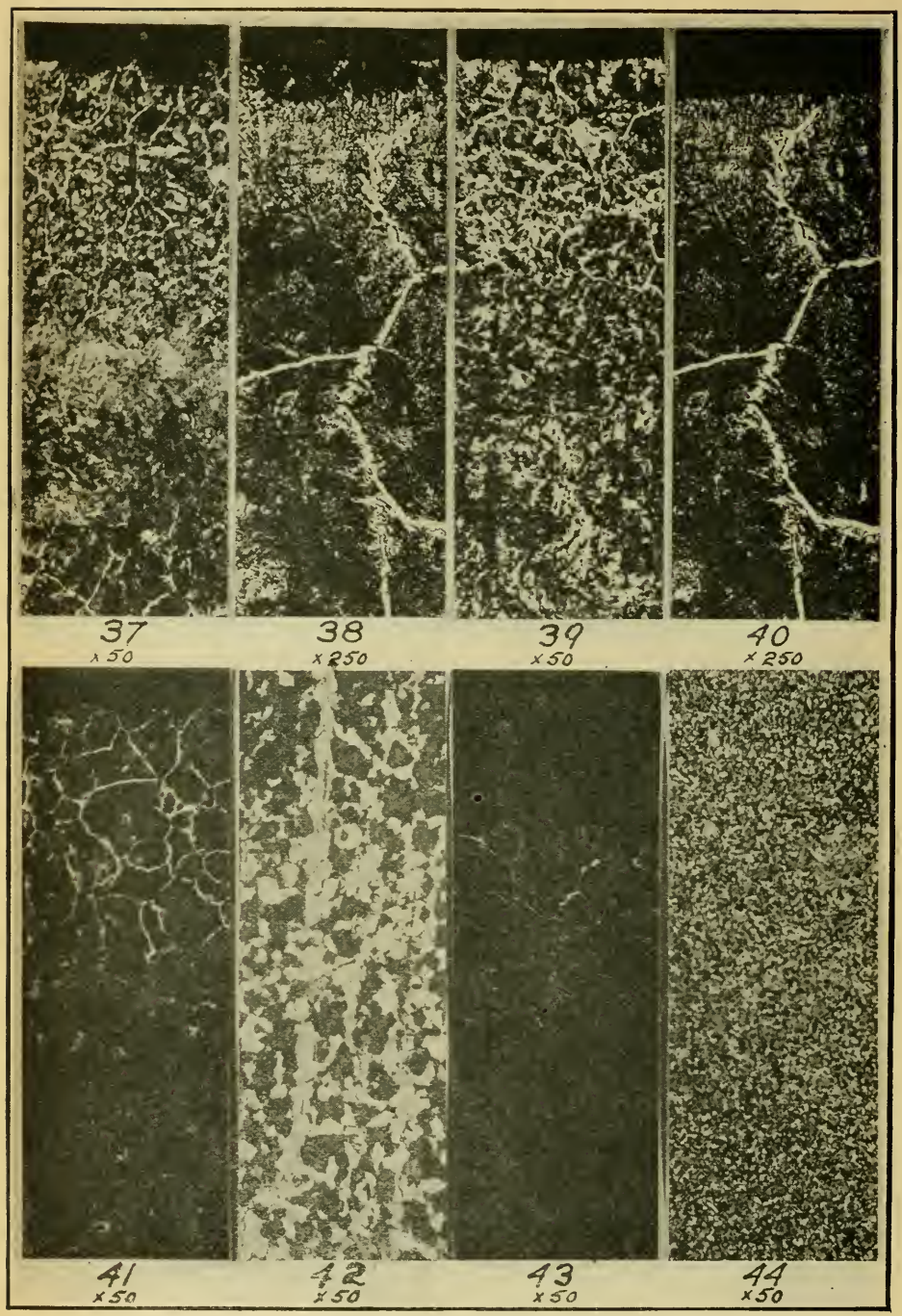
COLD ROLLED CARBON STEEL

Figs. 21 and 22, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 23 and 24, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. The outer surface hyper-eutectoid zone will be noticed in each of these specimens heated at 1700 degrees Fahr. Figs. 25 and 26, show the heat treated structure of case and the core of specimens carburized at 1700 degrees for 50 hours. Specimens were heated to 1475 degrees Fahr. and water quenched. Figs. 27 and 28, having same carburizing treatment were quenched in oil from 1585 degrees Fahr. and reheated and quenched in water from 1425 degrees Fahr.



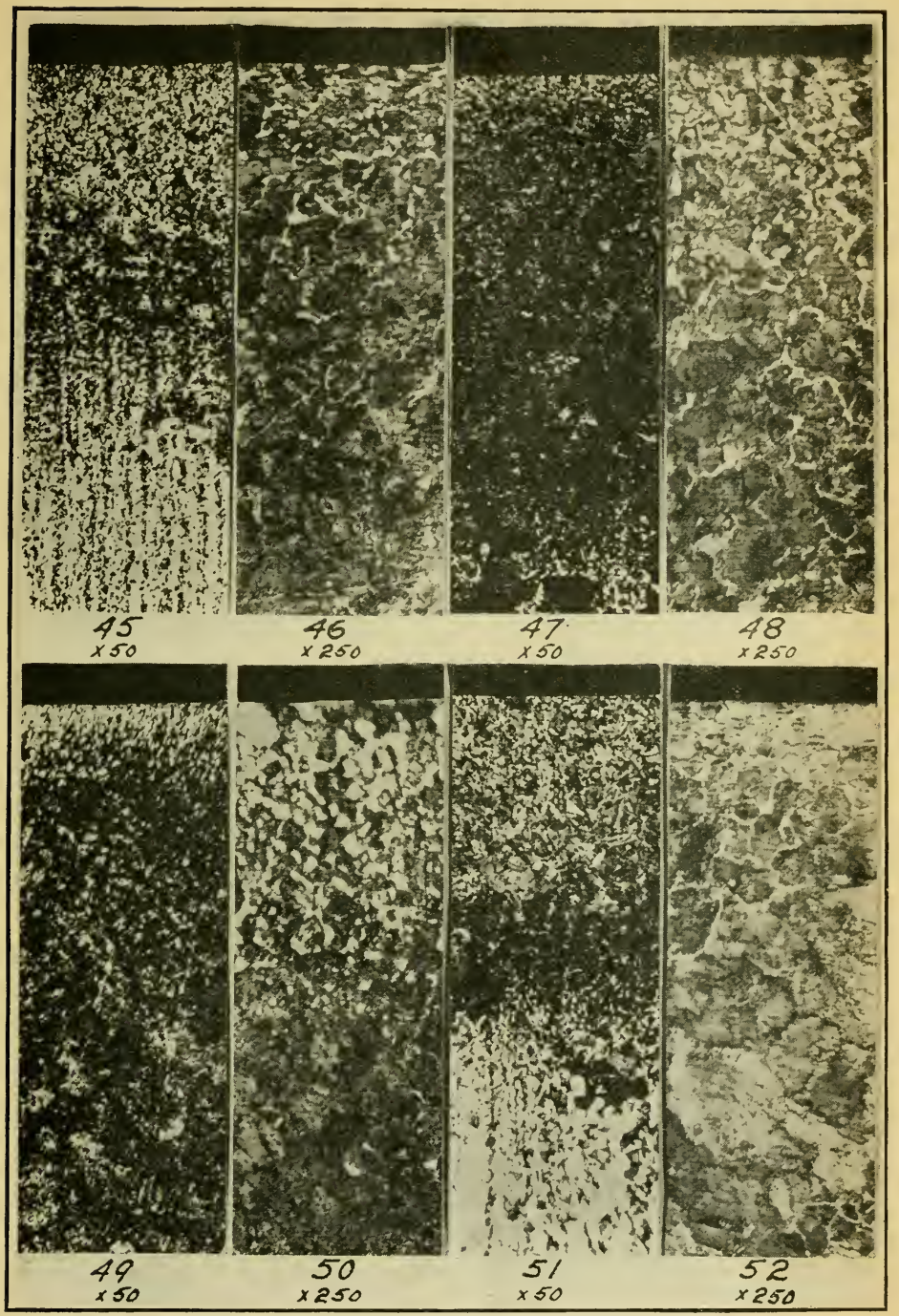
HOT ROLLED CARBON STEEL

Figs. 29 and 30, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 31 and 32, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 33 and 34, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 35 and 36, microstructure of specimens carburized for 5 hour at 1700 degrees Fahr. Note the increasing hyper-eutectoid layer as the time and temperature increases.



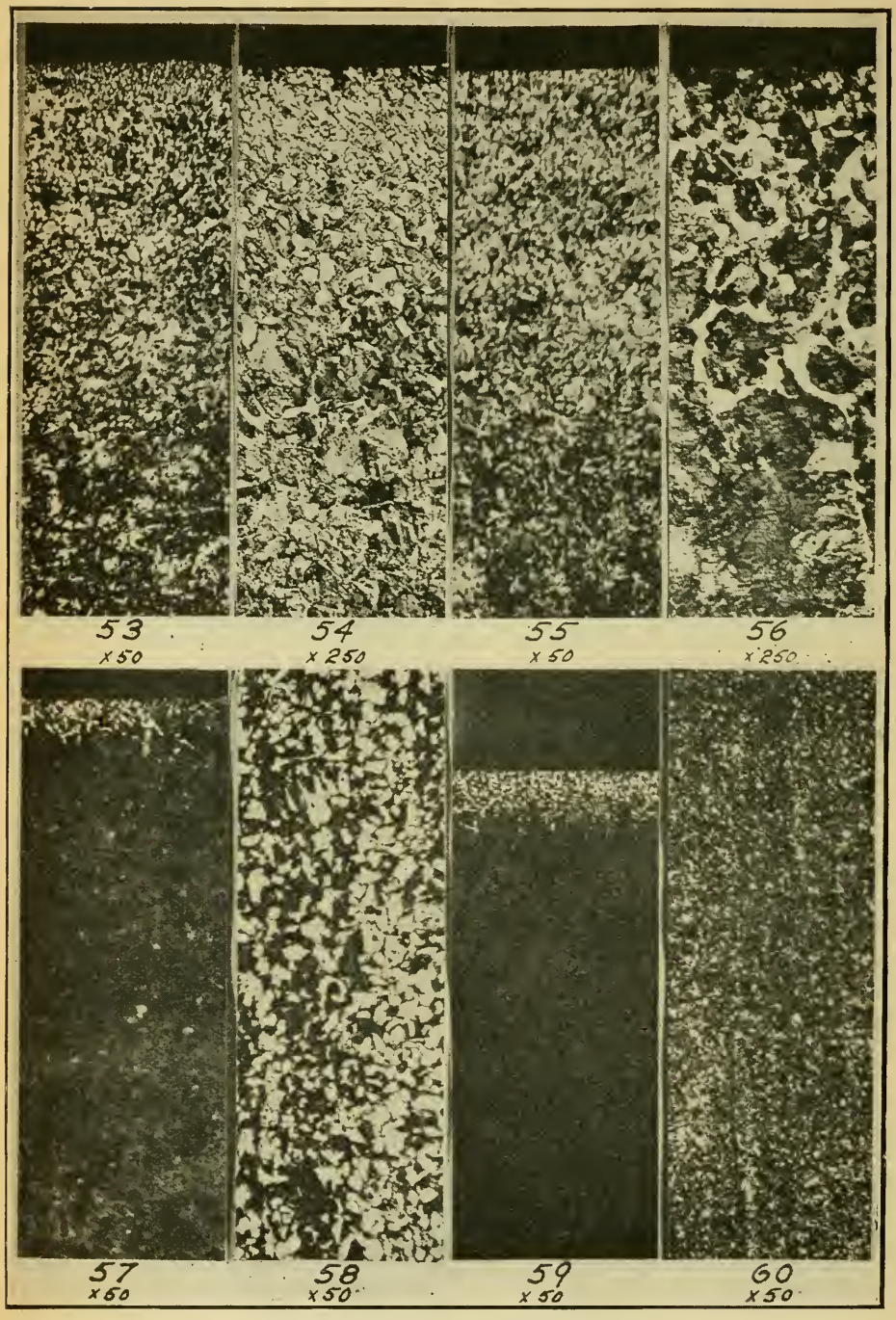
HOT ROLLED CARBON STEEL

Figs. 37 and 38, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 39 and 40, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. In 50 hours a 5/64 inch case has been produced made up of distinct hyper-eutectoid, eutectoid and hypo-eutectoid zones. Figs. 41 and 42, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1475 degrees Fahr. Figs. 43 and 44, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1585 degrees Fahr. and reheated and quenched in water from 1425 degrees Fahr.



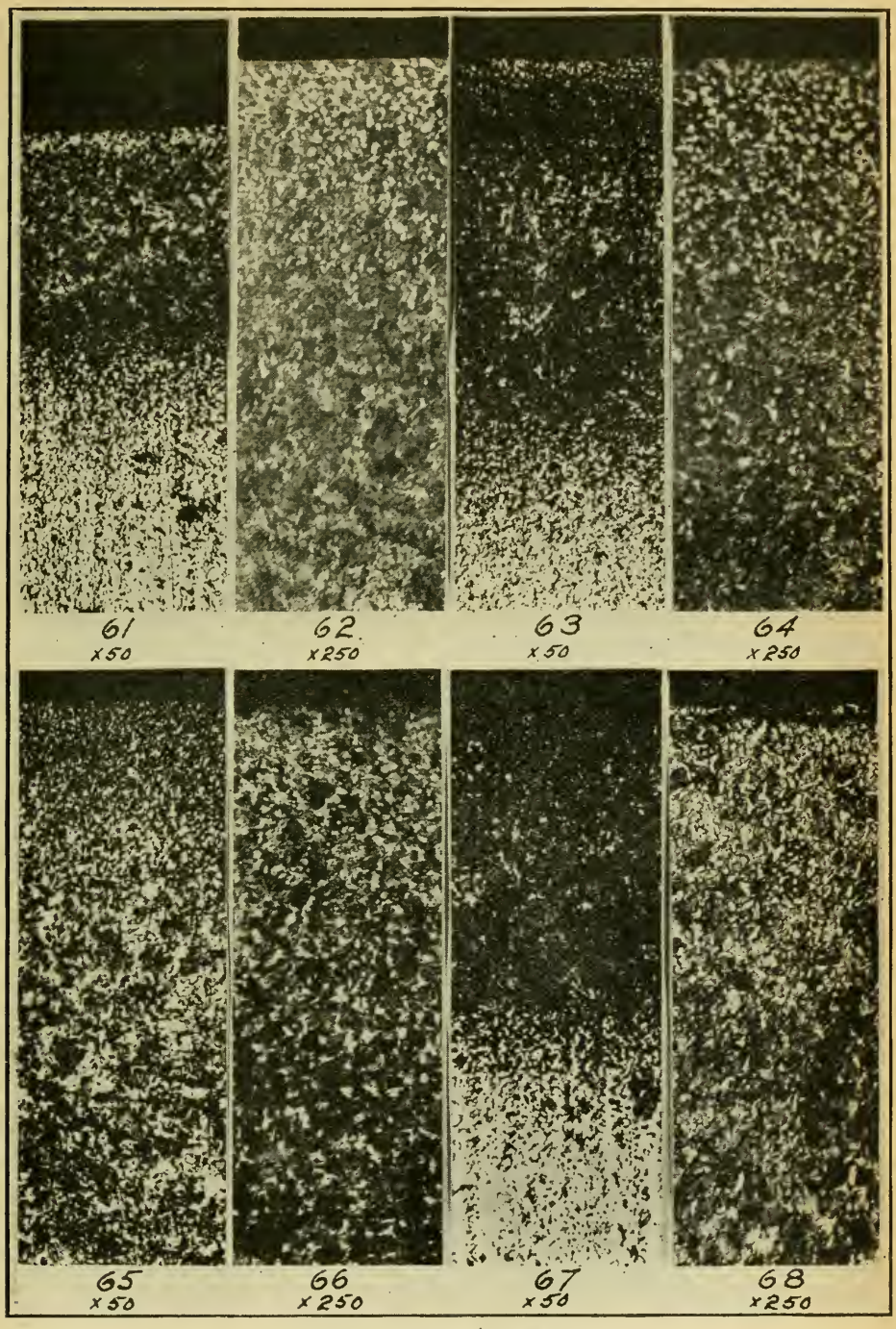
CHROMIUM SILICON MANGANESE STEEL

Figs. 45 and 46, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 47 and 48, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 49 and 50, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 51 and 52, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Note that the large pearlite grains of the carbon steel series is now absent.



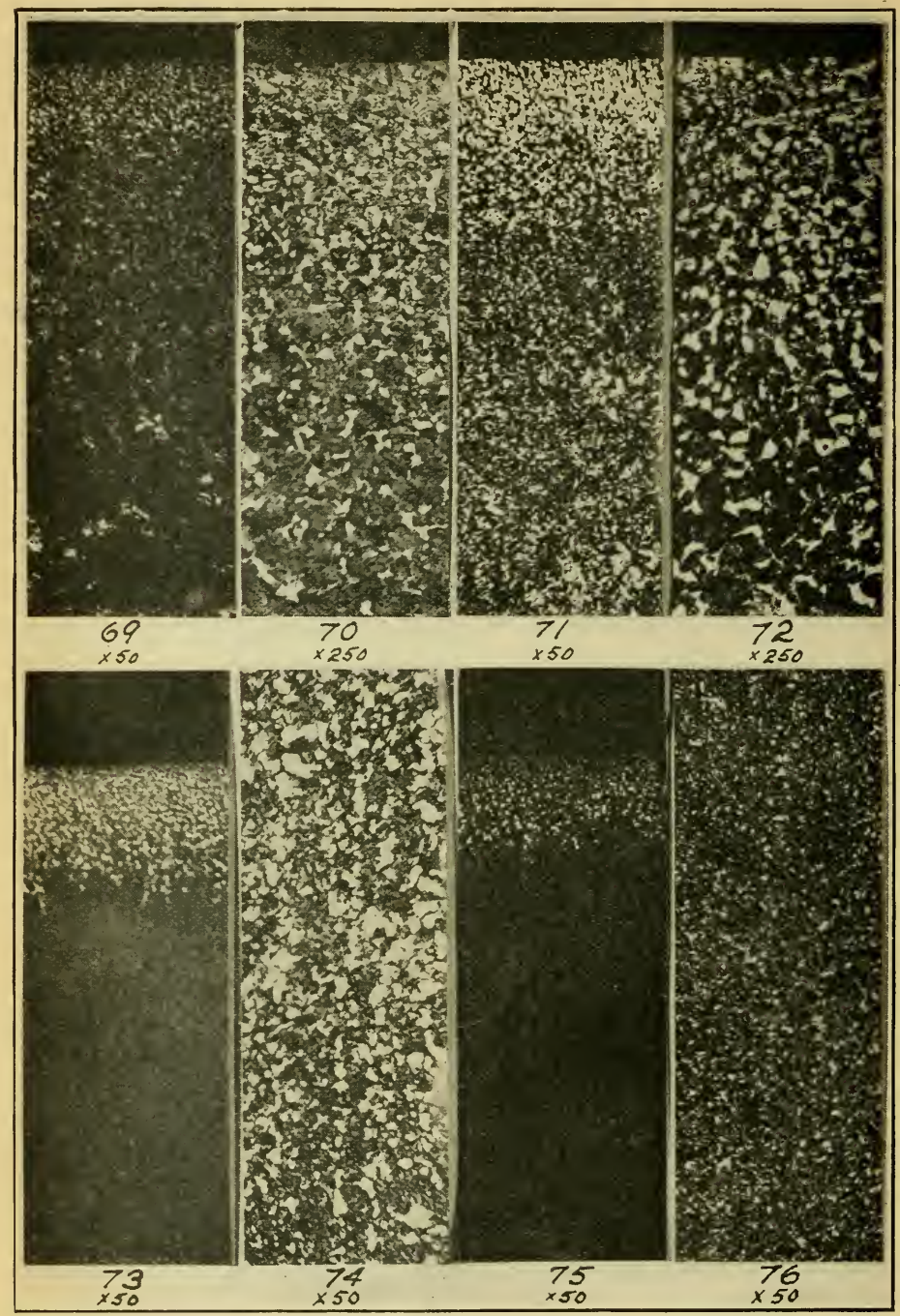
CHROMIUM SILICON MANGANESE STEEL

Figs. 53 and 54, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 55 and 56, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Note that the cementite network structure is absent in these specimens. Figs. 57 and 58, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1475 degrees Fahr. Figs. 59 and 60, case and core microstructure of 50 hours specimens carburized at 1700 degrees Fahr. quenched in oil from 1585 degrees Fahr. reheated and quenched in water from 1425 degrees Fahr.



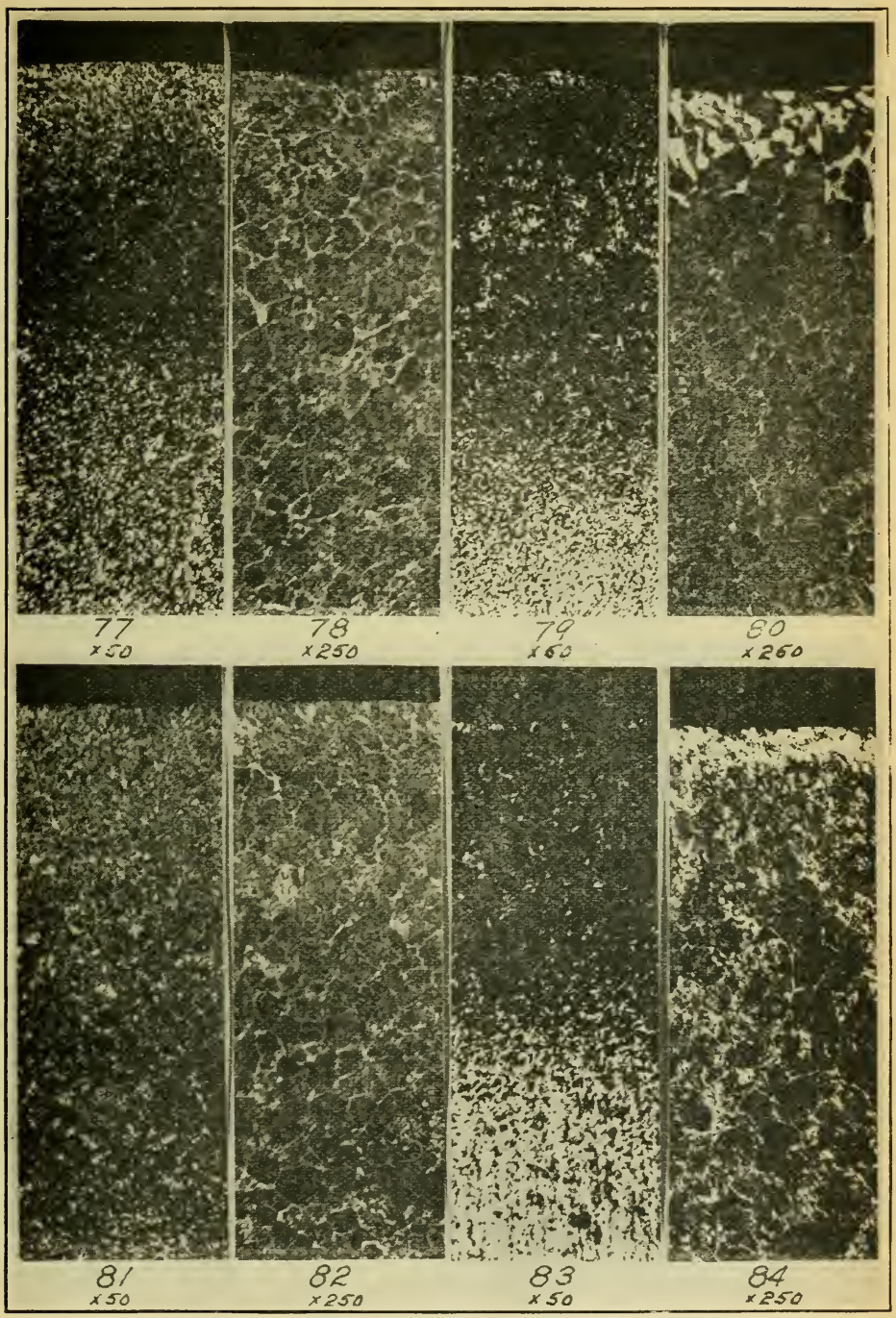
CHROMIUM VANADIUM STEEL

Figs. 61 and 62, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 63 and 64, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 65 and 66, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 67 and 68, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Vanadium produces a dense finely divided structure.



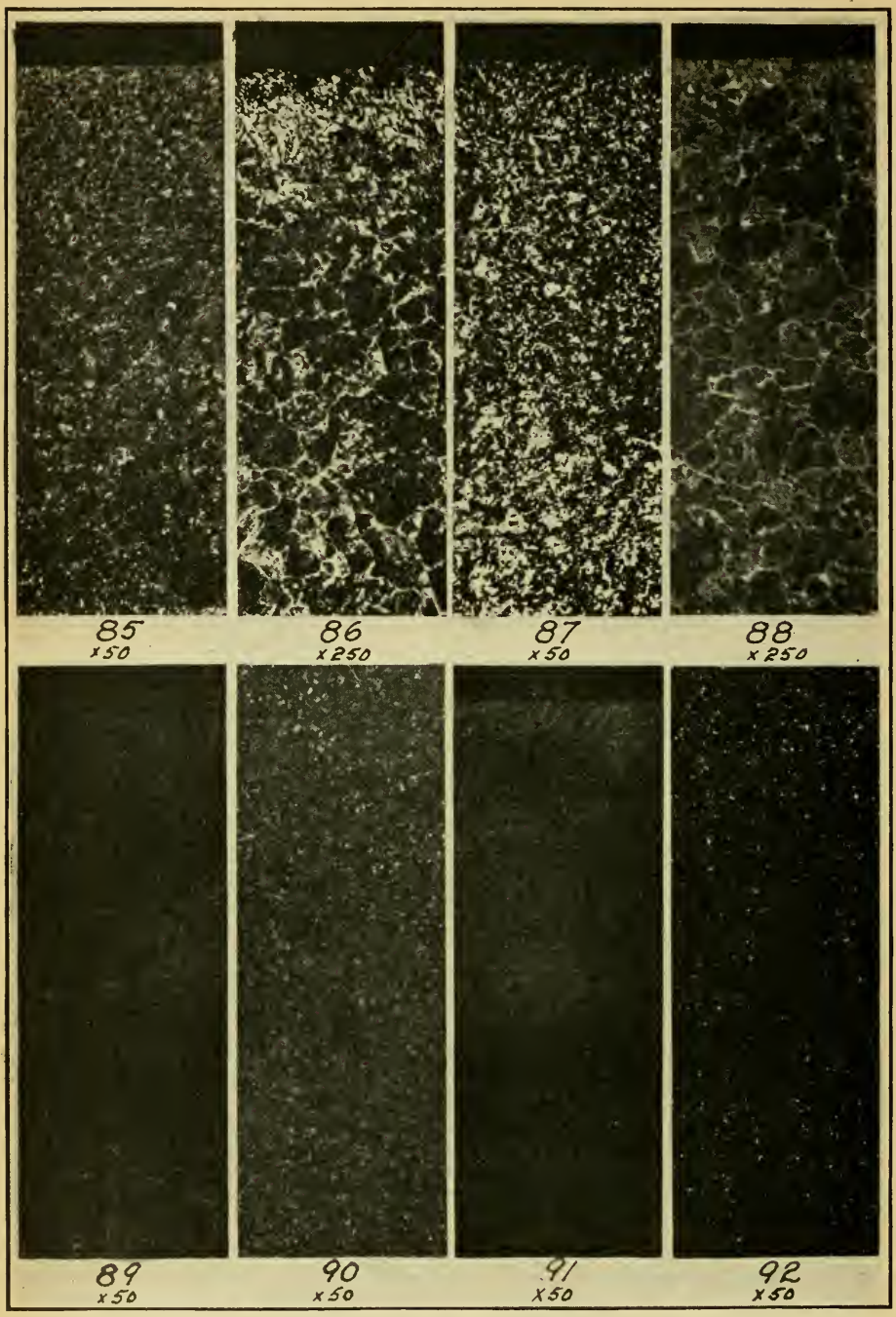
CHROMIUM VANADIUM STEEL

Figs. 69 and 70, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 71 and 72, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. We find the excess carbides occurring as globules uniformly distributed through the hyper-eutectoid zone. Figs. 73 and 74, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1525 degrees Fahr. Figs. 75 and 76, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1675 degrees Fahr., reheated and quenched in water from 1475 degrees Fahr.



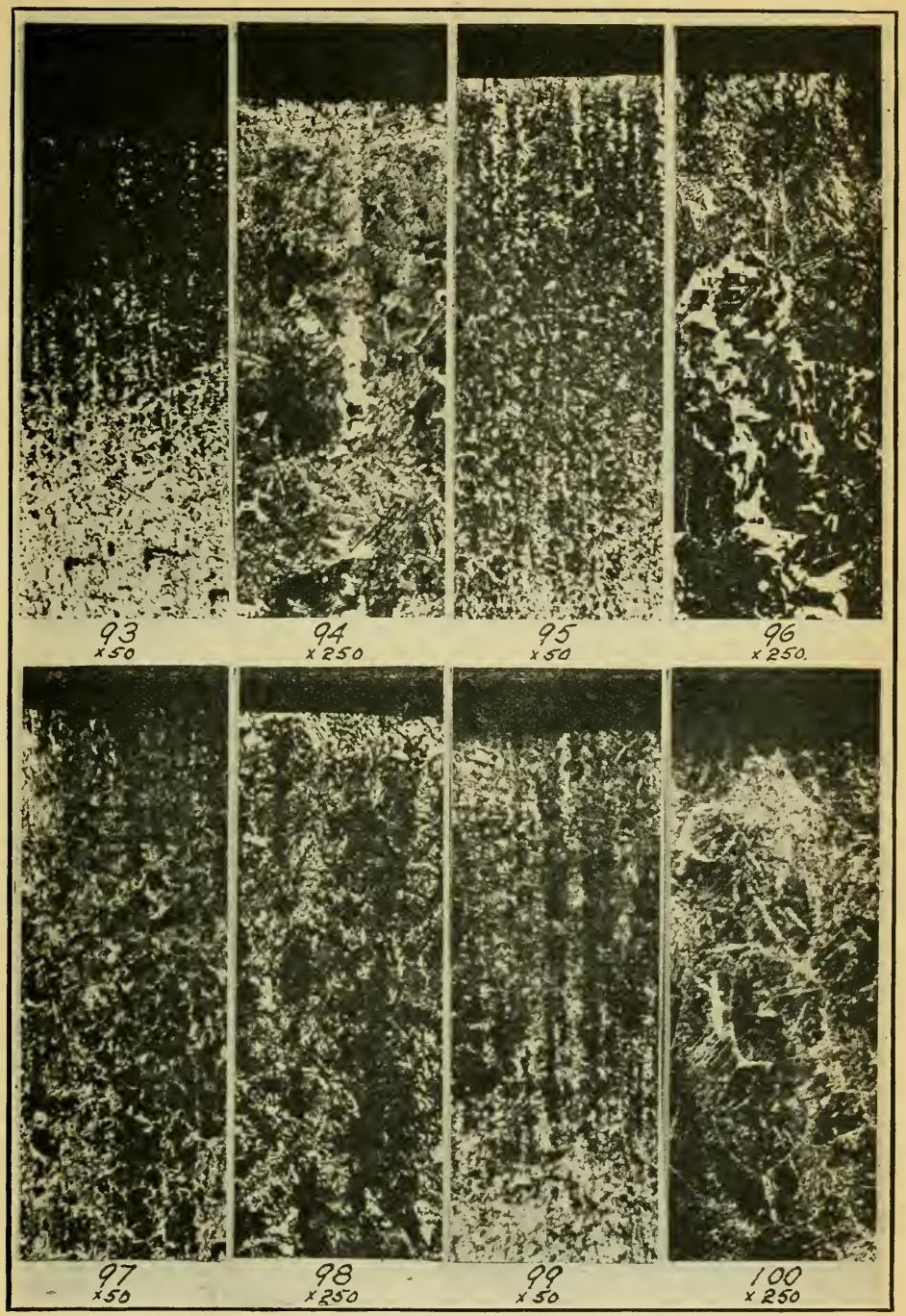
NICKEL STEEL—3½ PER CENT

Figs. 77 and 78, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 79 and 80, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 81 and 82, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 83 and 84, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Excess carbides occur as small globules and a fine network surrounding the grains.



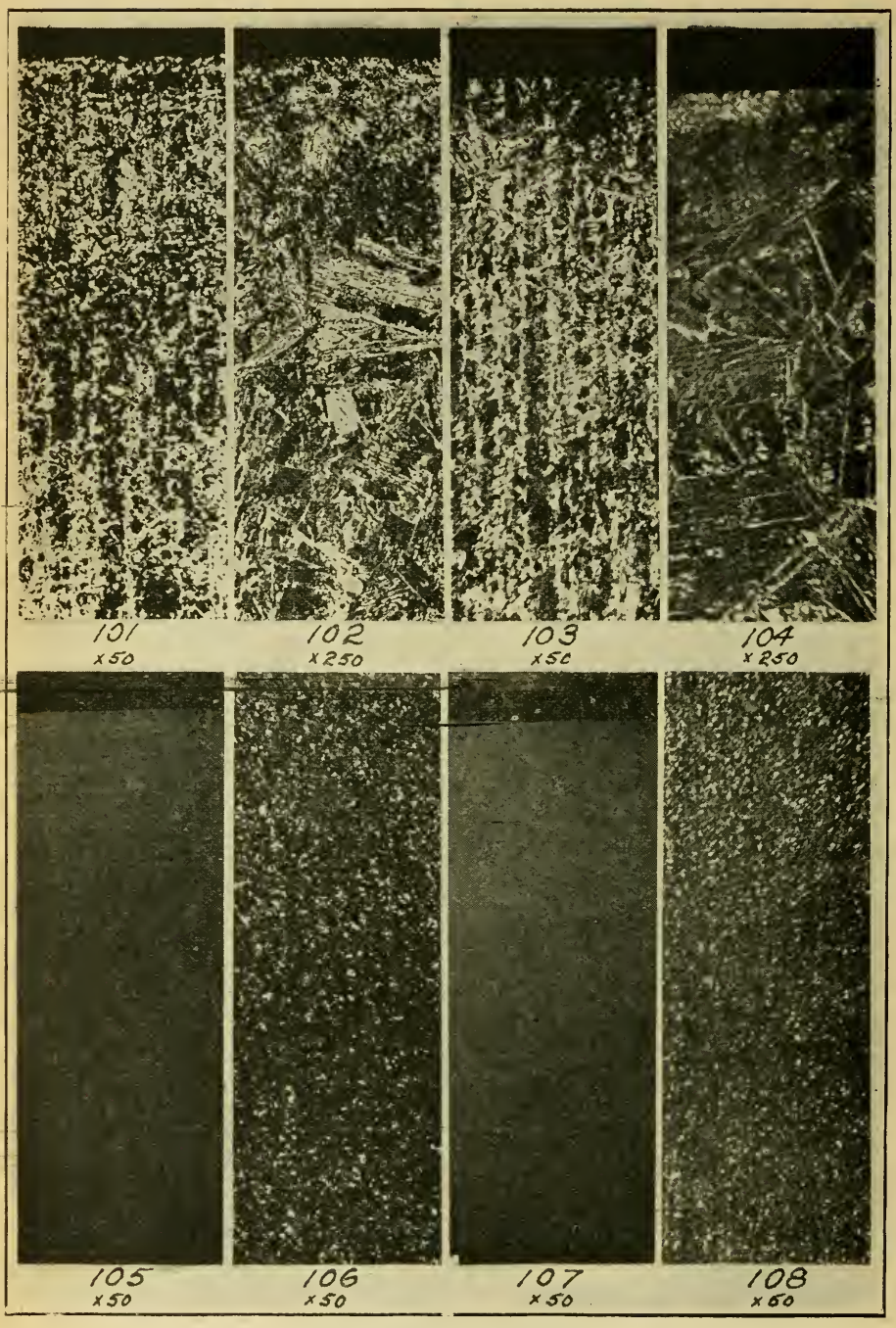
NICKEL STEEL—3½ PER CENT

Figs. 85 and 86, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 87 and 88, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Figs. 89 and 90, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1475 degrees Fahr. Figs. 91 and 92, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1525 degrees Fahr. reheated and quenched in water from 1350 degrees Fahr.



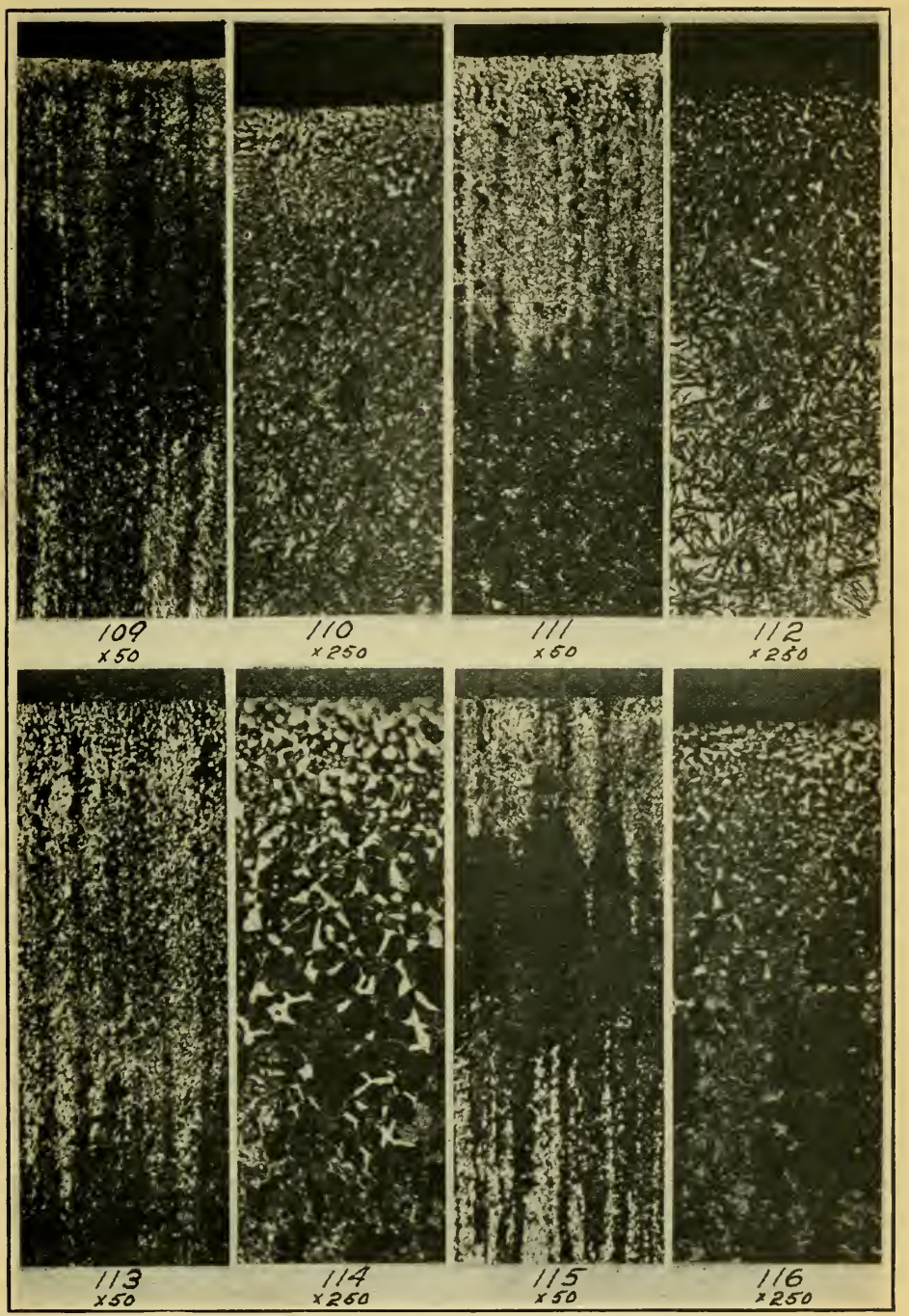
NICKEL STEEL—5 PER CENT

Figs. 93 and 94, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 95 and 96, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 97 and 98, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 99 and 100, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. No network is found in these micrographs and what carbide is visible appears to be distributed in small globules.



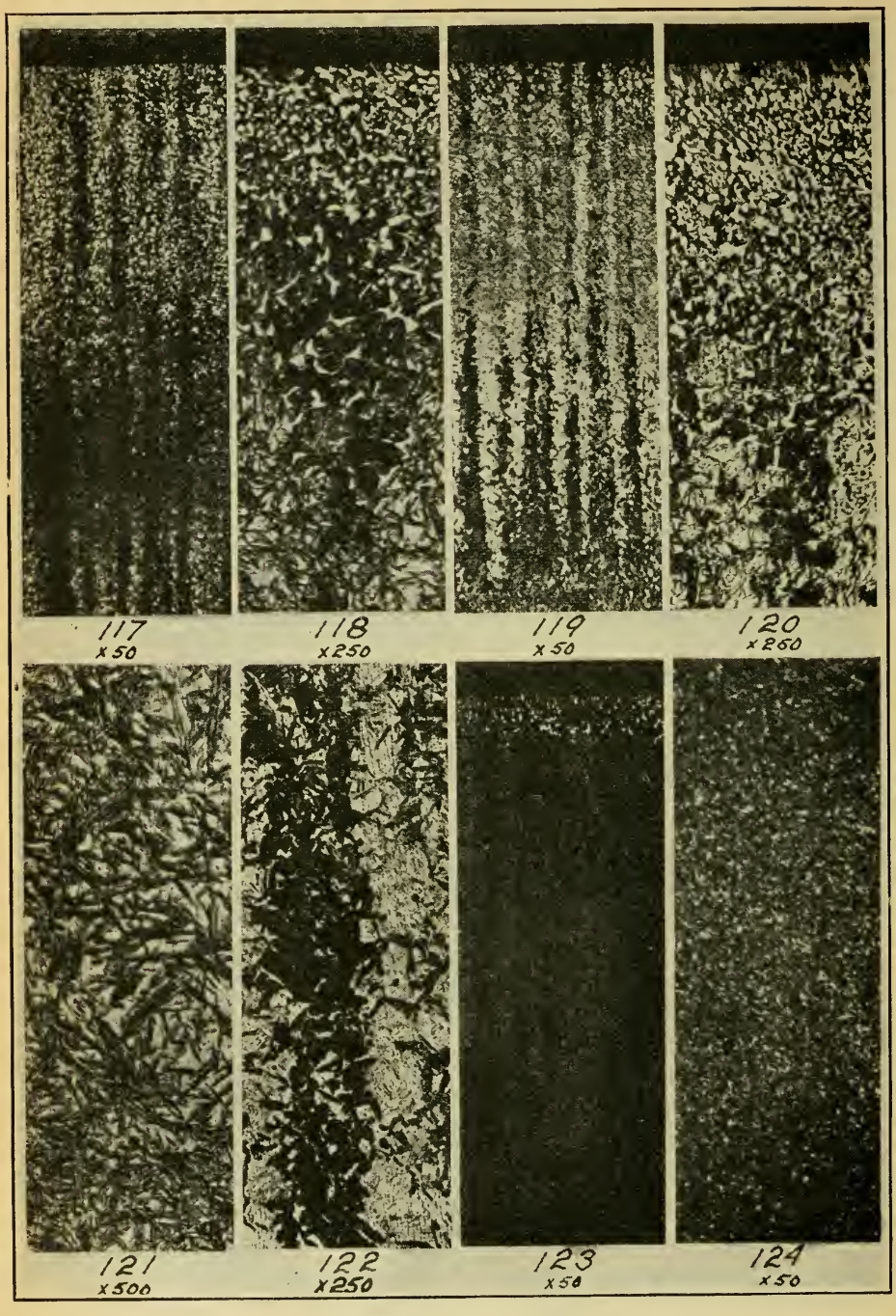
NICKEL STEEL—5 PER CENT

Figs. 101 and 102, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 103 and 104, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Figs. 105 and 106, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1475 degrees Fahr. Figs. 107 and 108, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1500 degrees, Fahr. reheated and quenched in water from 1300 degrees Fahr.



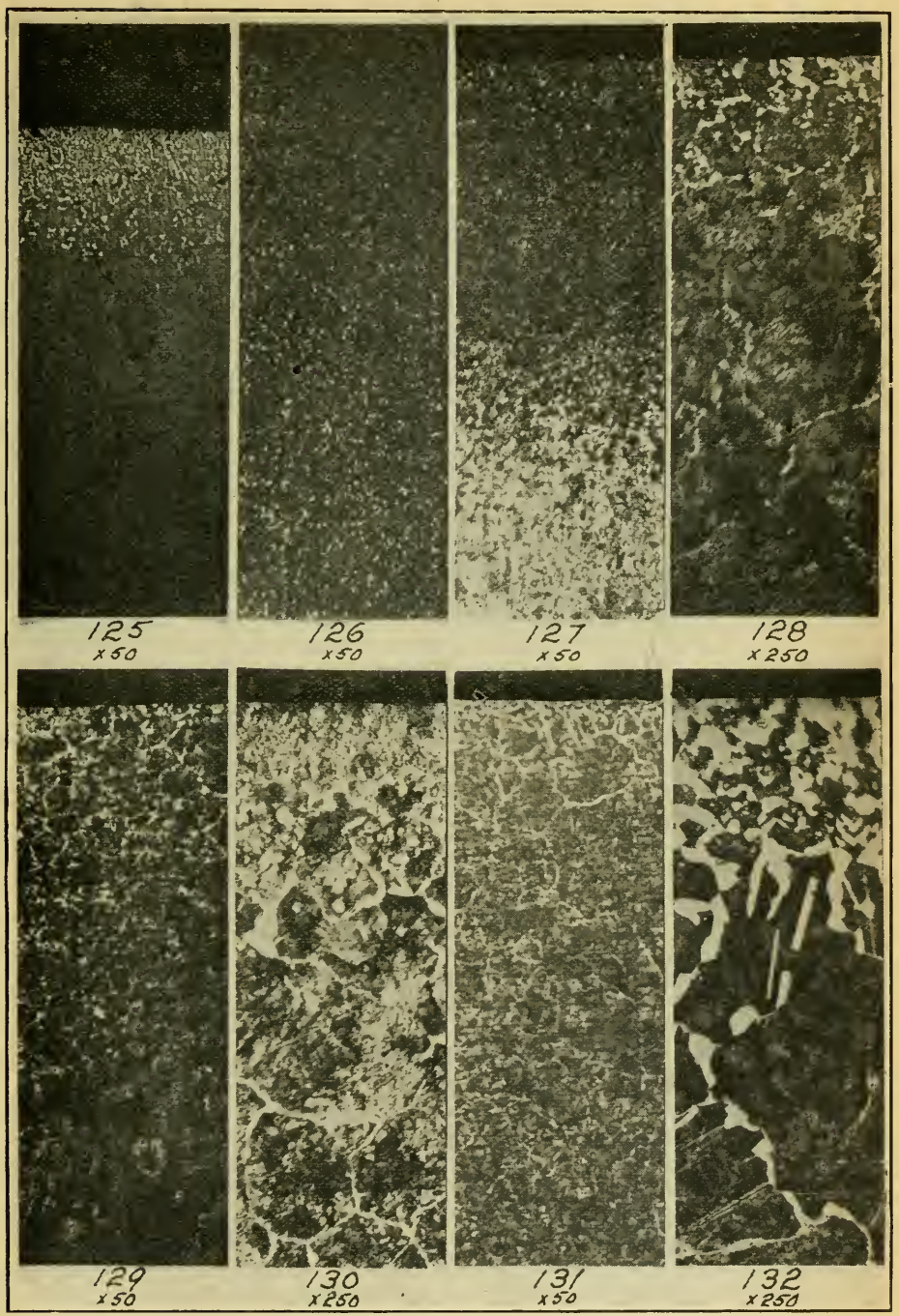
CHROMIUM NICKEL STEEL

Figs. 109 and 110, microstructure of specimens carburized for 5 hours at 1600 degrees Fahr. Figs. 111 and 112, microstructure of specimens carburized for 25 hours at 1600 degrees Fahr. Figs. 113 and 114, microstructure of specimens carburized for 50 hours at 1600 degrees Fahr. Figs. 115 and 116, microstructure of specimens carburized for 5 hours at 1700 degrees Fahr. Specimens cooled in the boxes show structures of austenite and martensite passing to troostite, sorbite and pearlite as the core is approached.



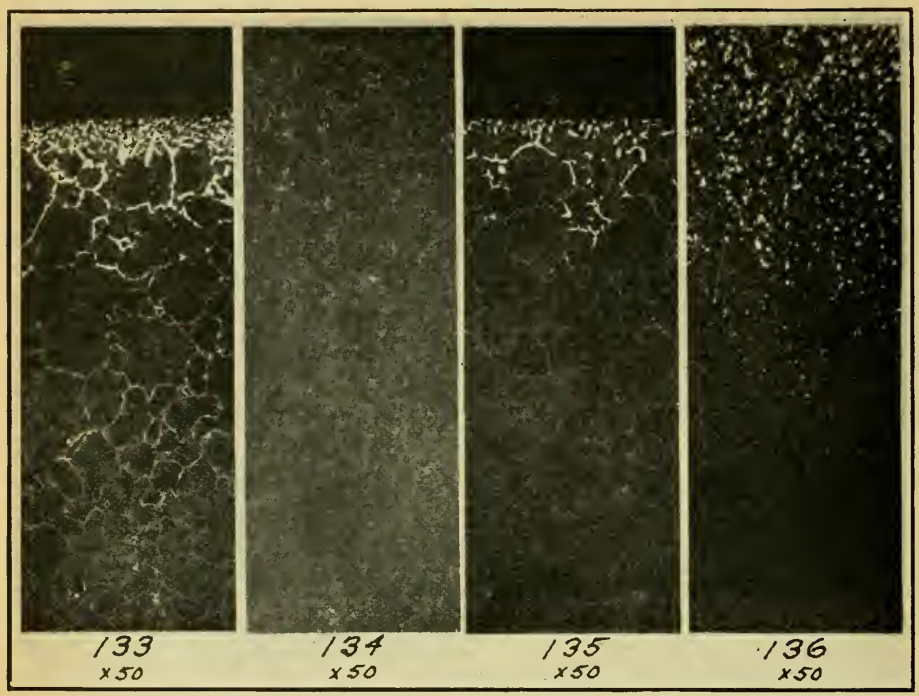
CHROMIUM NICKEL STEEL

Figs. 117 and 118, microstructure of specimens carburized for 25 hours at 1700 degrees Fahr. Figs. 119 and 120, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr. Figs. 121 and 122, microstructure of martensite and troostite, respectively. Figs. 123 and 124, case and core microstructure of 50 hour specimens carburized at 1700 degrees Fahr. quenched from 1500 degrees Fahr. in oil. Chrome Nickel steels have a strong tendency toward a streaky structure.



CHROMIUM MOLYBDENUM STEEL

Figs. 125 and 126, chromium nickel steel case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1600 degrees Fahr. reheated and quenched in oil from 1425 degrees Fahr Figs. 127 and 128, microstructure of chromium molybdenum steel specimens carburized for 5 hours at 1700 degrees Fahr. Figs. 129 and 130, microstructure of specimens carburized for 25 hours at 1700 degrees. Fahr. Figs. 131 and 132, microstructure of specimens carburized for 50 hours at 1700 degrees Fahr.



CHROMIUM MOLYBDENUM STEEL

Figs. 133 and 134, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in water from 1500 degrees Fahr. Figs. 135 and 136, case and core structure of 50 hour specimens carburized at 1700 degrees Fahr. quenched in oil from 1600 degrees Fahr. reheated and quenched in water from 1475 degrees Fahr.

A COILING AND HEAT TREATING PLANT FOR HELICAL SPRINGS

By William J. Merten

THE manufacture of helical springs involves the following steps:

1. Design.
2. Selection and fabrication of material.
3. Coiling.
4. Heat treatment.

The literature on this subject quite adequately treats the steps of design and selection of materials. The operations of coiling and heat treatment, however, while of equal importance has been left to the mercy of an untrained and unappreciative personnel. This condition is particularly evident in the type of control given the heat treating cycle, as an instance of this may be cited that it is now frequent practice to quench a spring immediately after it has been coiled without reheating, despite the fact that the benefits obtainable from the use of a correct heat treating process are well known to those skilled in the art. As a result of the prevalent comparative indifference to technical control, great variation in spring characteristics and life are the rule and not the exception. If we are to attain a high standard in spring performance, an adequate control of the metallurgical processes entering into the spring manufacture must be secured.

Manufacture of Springs

The chief factors to be considered in the manufacture of helical springs are the following:

I—Design:

1. Magnitude of principal stresses.
   (a) Magnitude of applied load.
   (b) Frequency of rate of application of maximum stresses.
2. Degree of eccentricity of applied load.
   (a) Amount of lateral displacement.
   (b) Active number of coils.
3. Material of requisite physical properties.

II—Manufacture of Spring Steel:

1. Melting of steel and manipulation of fluid and semi-fluid material.
2. Ingot discard to eliminate pipes, segregation, chipping out seams, and other injurious surface defects.
3. Rolling of ingots into billets—cropping and chipping of billets.
4. Rolling of billets into bars and rods.

III—Coiling of Springs:

1. Predetermined uniform rate of heating of entire bars to coiling temperature.
2. Correct coiling temperature. Defined as the temperature of least resistance of the metal to plastic flow without injuring the grain structure by over-heating. This temperature is between 1700-1800 degrees Fahr. for spring steel.
3. Uniform coiling temperature over the entire length of the bar.

A paper presented before the Indianapolis Convention. The author, William J. Merten, is metallurgical engineer, Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa.

Constant pitch, uniform diameter of coils, and correct length depend upon achieving an even temperature of the bars before coiling.

The labor involved in the adjustment (after coiling) to secure uniformity of pitch and length may be avoided by following this procedure.

4. Temperature and lubrication of mandrel. The usual practice of cooling mandrel by dashing on it cold water before, during, and after coiling, should be prohibited. Warping and cracking of the mandrel and the spring may be caused by the resultant local chilling.

Since the physical properties of the mandrel steel are at their maximum at approximately 300 degrees Cent., it would be to the advantage of the manufacturer to coil the springs on a hot mandrel. To lubricate the hot mandrel the use of a heat resistant dry material such as talc has been found practical.

On the more common sizes of springs ordinary air cooling is sufficient to maintain the mandrel at approximately 300 degrees Cent. For very large and long springs the use of air blast is suggested.

It should be noted that a better spring is secured, with less distortion and less internal strains, the higher the temperature of the mandrel during the coiling process.

5. Roller type guides. It is almost universal practice to employ sliding contact guides to hold the barstock while being coiled. However, the use of roller guides greatly reduces the embedding of hard scale and surface scoring of bars, inevitable with sliding contact guides.

6. Direct motor drive of coiling machines eliminates variations in coil diameters and pitch caused when using belt drive.

7. Cooling springs after coiling:

Slow and uniform cooling of springs to approximately 600 degrees Fahr. on heat insulated slabs to prevent distortion is necessary before heat treating the material. This is advocated because it facilitates the attainment of the correct quenching temperature and soaking time required for the completion of the grain refinement.

IV—Heat Treatment of Springs:

1. Heating for quenching.
   - (a) Predetermined uniform rate of heating.
   - (b) Correct quenching temperature and uniformity of this temperature over the entire spring.
   - (c) Quenching equipment.
   - (d) Quenching method.
   - (e) Quenching medium.
2. Heating for tempering or drawing.
   - (a) Uniform rate of heating.
   - (b) Correct tempering or drawing temperature.
   - (c) Tempering medium and equipment.
   - (d) Time period of tempering.

V—Testing of Springs:

1. Brinell Hardness test.
2. Compression test.

Helical Spring Coiling and Heat Treating Plant

1. Design of equipment.

In the design of the equipment, proper consideration must be given to the following:

(a) Quantity and quality production.

(b) Labor saving devices and fuel conservation.
(c) Low cost of installation.
(d) Low cost of maintenance.

2. Location:

Positioning of the equipment is of prime importance as it is necessary to insure a continuous operation with a minimum amount of manual labor and avoidance of cross transportation. A very convenient and rapid production plant layout for coiling and heat treating is shown in Fig. 1.

Furnace For Heating Bar Stock

The furnace shown in Fig. 2 is of the resistor type. This furnace is unique in that the heating chamber is of adjustable length, to permit obtaining maximum heating economy with either long or short bars.

The furnace is designed so that the heating chamber may be either 10 feet, 15 feet, 20 feet, 25 feet, or 30 feet long, by inserting or removing a partition every 5 feet after the first 10 feet. The heating chamber dimen-

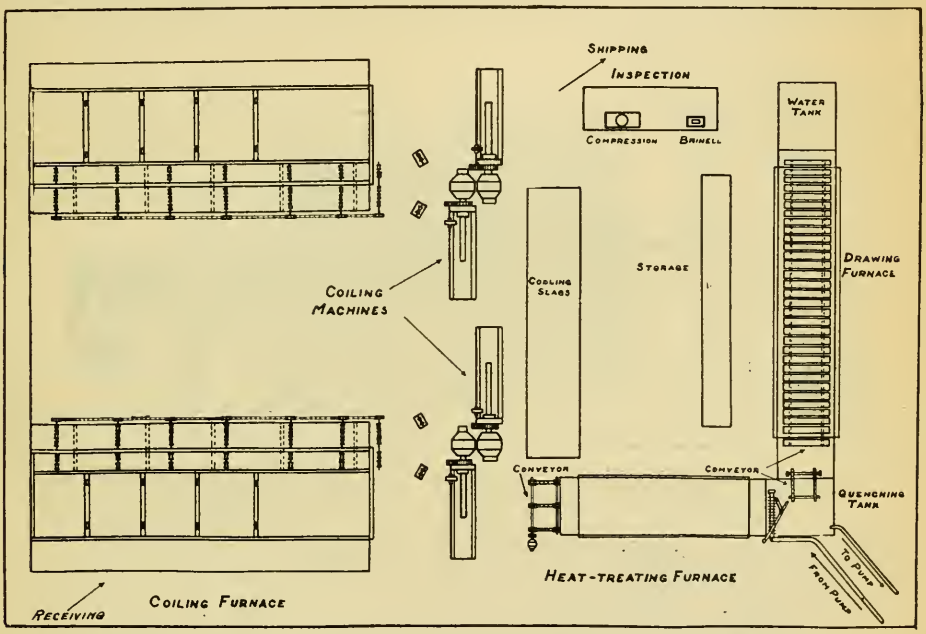


Fig. 1—Plan of a rapid production spring coiling and heat treating plant

sions are: 1 foot high, 5 feet wide, with a maximum length of 30 feet. The bottom of the furnace and the charging platform are sloped 1 foot in 10 feet. Standard heating units are mounted in the partition as well as in the side walls and bottom of heating chamber. The connections are made so that each chamber length is a separate electrical unit. The resistors in the movable partitions are automatically disconnected on raising the partition. The resistor grooves are open into the furnace chamber and in the bottom run at right angles to the longitudinal axis of the furnace. The surface of the refractory slabs for bottom resistors are grouted with finely pulverized porcelain and fireclay mixture to render it hard and resistant to abrasion, the fire clay serving as the binder. The charging platform is just wide enough to permit the charging of about 20 bars and its slope is a continuation of the furnace bottom. The charging end wall is about 3 inches short at the

bottom, providing an opening for entrance into the furnace chamber. Flexible asbestos aprons swinging toward the interior of the furnace form a seal insulating the heating compartment and giving access to it.

The charge passes through furnace by gravity and discharges at conveyor side onto a series of rolls which feed the bar stock to either one of two coiling machines. The placement of the bars on the roller conveyor is controlled by a lowering rack at exit end of furnace. The rack is in turn controlled by a switch to occupy a position slightly above the rolls.

The two coiling machines are set against each other as shown in Fig. 1.

The furnace assures uniform heating of bars for coiling at a correct rate and attainment of the desired coiling temperature over the entire length of the bar.

The sloping bottom, charging platform and roller conveyor at discharge door are labor saving devices of decided value, the furnace operator being able

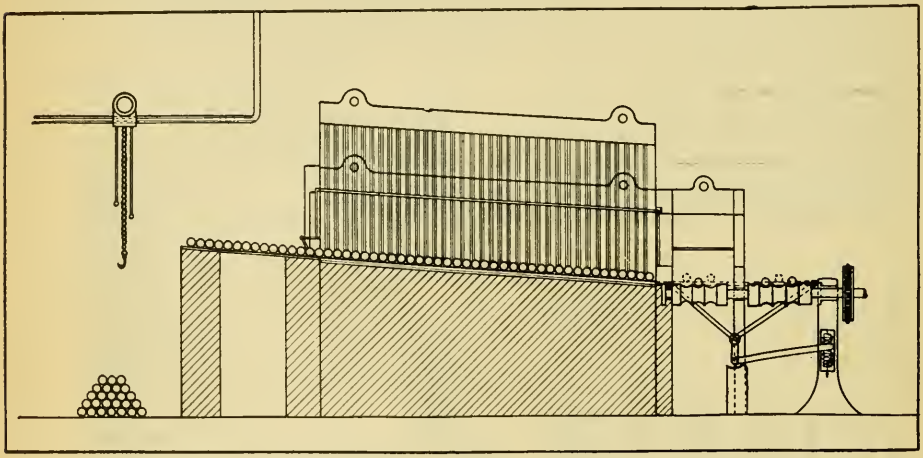


Fig. 2—Section through a resistor type electric furnace used in heating steel to be coiled into springs. This furnace is unique in that the heating chamber is adjustable in length, which permits of obtaining maximum heating economy with either long or short bars

to take care of the charging, heating, and the feeding of the rod to the coiling machine without difficulty.

The capacity of the furnace is about 60—1 inch bars per hour, or 480 bars per 8 hour day. The coiling of a spring takes nearly 2 minutes, consequently two coiling machines are fed continuously from this one furnace. By slight variations of procedure, different types and sizes of springs may be handled simultaneously.

The coiling machines need no special discussion. The direct motor drive is of such simplicity that its application and merits for this purpose are self-evident.

The choice of guides and mandrels is of utmost importance. The mandrel should be made to slightly taper about 1/32 inch per foot and preferably of a 0.30 per cent carbon, 3½ per cent to 5 per cent chrome steel.

The furnace is positioned so that its discharge end is practically at right angles with the head ends of the two coiling machines, No. 1 coiler feeding the bar over the mandrel for right handed springs and No. 2 under feeding it for right handed springs, the motors being set in batteries of two.

After coiling and marking, the springs are placed on cooling slabs, shown in Fig. 1, insulated with iron scale (Fe_3O_4), lime or sand, and cooled to black heat of about 600 degrees Fahr. and then charged into heat treating furnace. However, immediate heat treatment can be permitted only when all variables influencing the uniformity of pitch, diameter of coils, and lengths are reduced to a minimum by a careful coiling method.

A resistance type of furnace is also employed to heat springs for the quenching operation. The dimensions of heating chamber are 1 foot 6 inches high, 4 feet wide, and 15 feet long. It has a sloping bottom of 1 foot in 15 feet, with a horizontal section about 5 feet long at discharge end. The sloping bottom insures continuous feed. A double row of about 60 springs of approximately 5½ inches diameter and up to 22 inches in length constitute a charge. The available time for heating springs in the furnace from 600 to 1500 degrees Fahr. is 1¼ hours, giving an average rate of temperature

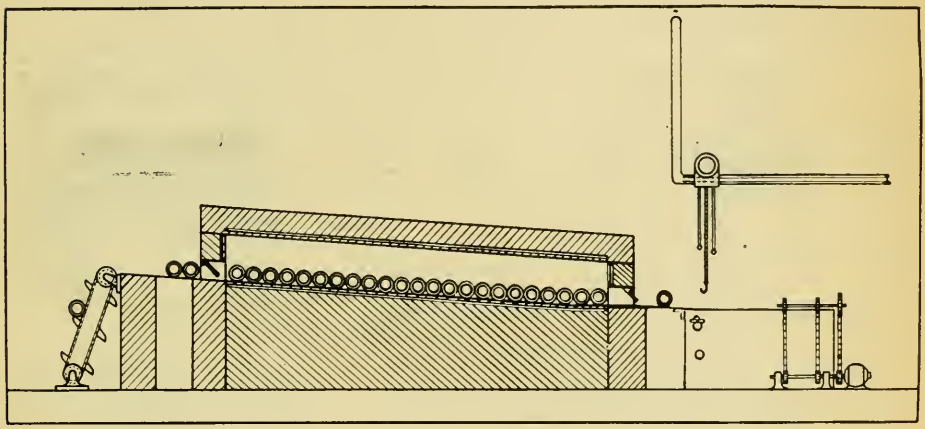


Fig. 3—Section through a resistance type electric heat treating furnace used in heating springs prior to quenching

increase of 12 degrees Fahr. per minute, this is in order to insure proper uniform grain refinement.

The charging is performed with a sprocket chain conveyor shown in Fig. 3, which deposits the spring upon the sloped charging platform where it is directed into the furnace by the furnace operator. No doors are provided for this furnace, the front and rear openings being insulated by flexible asbestos aprons. The ribbon type resistor units are open into the heating chamber. At the bottom they are inserted parallel to the longitudinal axis of furnace. The surface of the bottom is grouted for abrasive purposes with hard porcelain powder and fire clay mixture, similar to the bottom of coiling furnace.

The spring, when at the correct temperature of approximately 1500 degrees Fahr., is drawn into a perforated scoop shown in Fig. 4 for quenching. This scoop serves to maintain the symmetry of the spring and by means of the hanger construction, correctly places the spring in the quenching medium. The perforations are of such diameter and mesh that sufficient strength with least contact surface is obtained. The curvature of the scoop corresponds to the curvature of the coil.

Quenching Equipment

The quenching equipment consists of a steel tank 3 feet deep, 4 feet wide

and 6 feet long, filled with oil agitated or sprayed so as to insure uniform hardness of internal and external parts of the spring. Failure of helical springs usually starts from some internal point, approximately 45-60 degrees from the inner line. The examination of such fractures invariably revealed a decidedly soft steel at the origin of failure, caused by retardation of rate of cooling, resulting from the presence of a gas pocket in the oil.

The life of a spring subject to heavy service varies with the degree of uniformity of the proper hardness and toughness. It is obvious that a quenching system should produce springs having uniform and consistent properties and therefore a long life in service.

The oil tank has a capacity of 550 gallons. The circulation through the cooling system is at a rate of about 175 gallons per minute or the oil renews every 4 minutes. A spring having a weight of 50 pounds is quenched in this tank from 1500 to 200 degrees Fahr. in 1¼ minutes, or at a rate of 20 degrees Fahr. per pound of steel per minute. When the spring has cooled

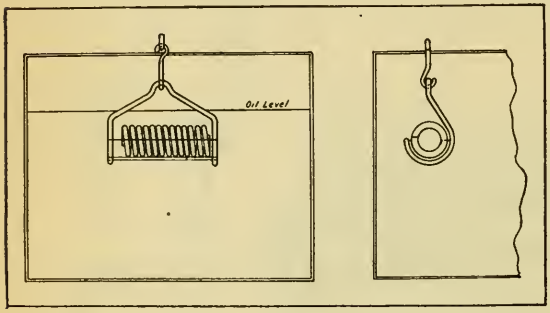


Fig. 4—Perforated scoop used in quenching coil springs. The scoop serves to maintain the symmetry of the spring and by means of the hanger construction, correctly places the spring in the quenching medium.

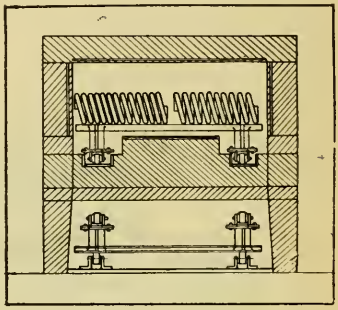


Fig. 5—Section through a resistor type drawing furnace showing the arrangement of the springs in the furnace.

to 200 degrees Fahr. it is placed upon the conveyor and delivered to the charging platform of the tempering or drawing furnace.

The scoop is fastened to the hook end of a small electric hoist so that positioning after receiving the hot spring and immersion in the oil is easily accomplished. The quenched spring should be drawn as soon as possible after completing the quenching operation.

Drawing or Tempering Equipment

The drawing equipment also utilizes the resistance type of furnace equipped with a continuous conveyor. The low operating temperatures of 800 to 900 degrees Fahr. permit the use of calorized sheet carrier materials for the shoes and gray iron, malleable iron and wrought iron for the other parts of the conveyor. The furnace is 1 foot, 6 inches high, 4 feet wide, and 25 feet long. The speed of the conveyor bottom is regulated to provide a speed of about 25 feet per hour. The spring is therefore drawn for one hour within the temperature range specified above, after which it is ejected and cooled in tepid water. It is then ready for inspection including Brinell hardness and compression tests. The electric features of the drawing furnace are similar to those of the others except that the stationary bottom is replaced by the conveyor. Fig. 5 illustrates the arrangement of springs in the drawing furnace.

Summary

It may be observed that the layout of this plant insures a maximum econ-

omy of labor and materials consistent with securing a high grade product constantly under technical control.

The features that merit particular consideration are:

1. Improved furnace design.

The three electric furnaces—the first for heating preliminary to coiling, the second for heating for quenching, the third for heating for drawing—are designed with automatic feed for maximum economy.

2. Appropriate design for securing proper temperature control with a minimum of power consumption.

3. Twin coiling machines with direct motor drive.

4. Special design of quenching mechanism to assure uniform hardness on all parts of spring.

5. Continuity of flow of material from raw stock to completed spring.

The output of a plant of this type would be approximately 450 springs of 50 pounds each on an 8 hour day basis.

The total floor space required is approximately 4000 square feet.

The output of the coiling machines is practically a fixed quantity for small and large springs. In order, therefore, to utilize the equipment effectively while manufacturing springs smaller than 50 pounds, an alternative arrangement, consisting of second coiling furnace and twin coiling machines is suggested and shown on Fig. 1.

The investment for a single unit plant and equipment exclusive of building should be approximately $25,000.00.

The personnel required to operate the plant would consist of:

1—Foreman, who also assists the inspector.
1—Inspector.
1—Inspector's assistant.
6—Operatives.
1—Man in Receiving department.
1—Man in Shipping department.

Receiving and shipping men perform clerical duties also.

The principal items entering into the cost of spring manufacture are:

I. Labor:
(a) Direct labor of the operatives, receiving and shipping men.
(b) Salaries of inspectors.
(c) Salary of clerk.
(d) Indirect labor of the inspection, supervisory and clerical forces.

II. Material:
(a) Raw stock for spring steel.
(b) Fuel.
(c) Quenching oil.

III. Burden and Overhead:
(a) Depreciation of equipment.
(b) Interest on investment.
(c) Overhead on items I, II and III.

On the basis of present costs of labor and materials, the cost per pound of spring manufactured in the plant described wherein complete technical control of the product is secured, would approximate $.03. The average 50 pound spring would cost therefore, about $1.50.

THE ELECTRIC FURNACE AS IT EFFECTS OVER-ALL COST OF HEAT TREATED PARTS

By C. L. Ipsen

AS WE trace the development of the art of steel treating from remote times down to the present, we note that the advance has been associated with a progressive change from one type of heat source to another. Thus we pass from the early hand forge, burning wood or charcoal, successively through the coal and coke furnaces, the oil furnace and the gas furnace, until we come finally to the electric furnace. It is especially noteworthy that each change in the development has been to a fuel or heat source having a higher cost. While these progressive changes have not been universally adopted, it can not be doubted that they have been made on a sound economic basis, since there have been no backward tendencies.

The higher priced, improved heat source, has successfully withstood the competition of existing fuels, which indicates that there are other factors of greater importance in the heat treatment of steel than furnace operating costs, a fact which is not commonly recognized by the average furnace user. Most prominent among these other factors are:

1. Reduced cost of subsequent operations.
2. Reduction of the number of rejections.
3. Increased life of product with more satisfactory service.

In order to determine to what extent these factors will overcome higher furnace operating costs, an accurate cost analysis is necessary, which will show the influence of furnace operating costs on the cost of the finished product.

Table I has been prepared for this purpose, and shows actual ultimate costs of several familiar heat treated parts, together with the total cost of heat treating, as well as the cost of electricity used as a heat source. Attention is directed particularly to the last column, in which is shown the part that electricity plays in the ultimate cost. The electric power rate for all items is $.015 per kilowatt hour.

The various dies, items 1 to 6, are heated in the furnace shown in Fig. 1. A similar furnace is used for preheating, and an electrically heated oil bath is used for drawing. These furnaces, and the oil tempering bath, are maintained at temperature constantly throughout the day, and the cost of the electricity thus used is apportioned among the dies treated over a certain period. If the furnaces could be operated at full capacity constantly, the cost of electricity would be from 10 to 20 per cent of the values given.

This furnace, shown in Fig. 1, has been run constantly for 25 months at a temperature of 1500 degrees Fahr. For the first 9 months of this period it was run 24 hours a day, 7 days a week. Since that time it has been run from 4 A.M. to 4 P.M., an automatic time clock being used to throw the power on in the morning and off in the afternoon.

During the 25 months of operation there has been no interruption of service, and the only expense incurred has been the replacement of a relay coil on the control panel, at a cost of less than one dollar. A metallic resistor heating element of the construction shown in Fig. 9 is used. No deterioration in this resistor is apparent after the 25 months continuous service. The only

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A paper presented at the Indianapolis Convention of the Society. The author, C. L. Ipsen, is designing engineer, Industrial Heating Department, General Electric Co., Schenectady, N. Y.

attendance necessary is occasional oiling of the automatic control instrument and putting in a roll of record paper, the controlling of the temperature and the throwing on and off of the power being automatic. This information is given to show that the electric cost, as indicated in Table I, is the only expense incurred. There is no continuous repair bill.

We have then, as the total cost of electricity in heat treating these dies, an amount equal to 0.3 of one per cent of the ultimate cost of the die. Subtracting from this the cost of other kinds of fuel, will give the amount that must be offset by these other factors such as reduction of rejects, etc. In the case of this die heating furnace, the cost of electricity is practically the same as the cost of oil. Extensive tests were run on similarly constructed oil and electric furnaces, to determine the policy of this company on future tool

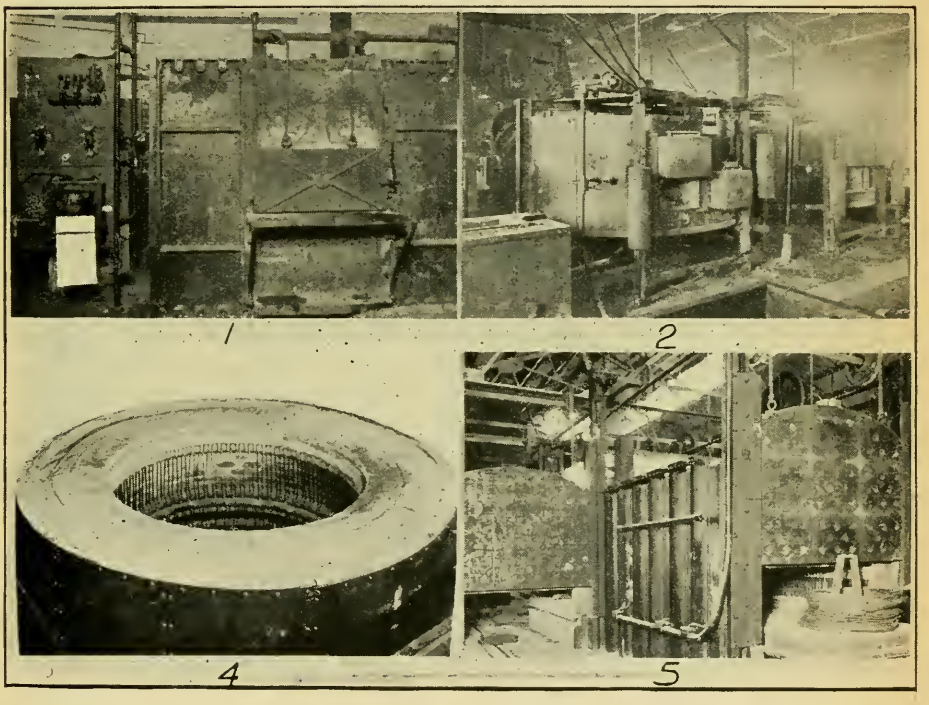

Fig. 1 Electric furnace similar to the one in which items 1 to 6 of Table I were heated.

Fig. 2 Electric furnace of the rotating annular ring hearth metallic resistor type.

Fig. 4 General construction of a gun tube and jacket heat treating furnace used extensively during the World War.

Fig. 5 Recuperative electric furnace used for annealing steel wire. The charge after being heated to the proper temperature is placed in the cooling chamber where it imparts its heat to the incoming cold charge.

treating furnace installations. The cost of operating the oil furnace was $.23 per hour with oil at $.13, and the electric furnace $.10 per hour. With oil at its present level the costs are thus about equal.

However, in certain localities this would not be the case, and we must then look to these other factors to justify the use of electric furnaces. In the case of these dies the most prominent of these factors are the reduction of rejections, lower cost of subsequent operations, and longer life of dies. Unfortunately, accurate data are not available on these factors, but in the opinion of the foreman in charge of the work they amount to several

per cent, the reduction in rejections alone being over one per cent or three times the total cost of electricity.

Items 7 to 12 inclusive are at the present time treated in an oil furnace, the cost of electricity having been calculated on the basis of experience with electric furnaces handling similar work. Electric furnaces are contemplated for these parts, as a cost analysis indicates that the increased cost of electricity will be several times offset by the improvement in quality.

A furnace with a rotating annular ring hearth, shown in Fig. 2 is used for heating gears, item 13 of Table I. The cost of electricity for heating these gears is based on thirty days operation, 9510 gears weighing 39,107

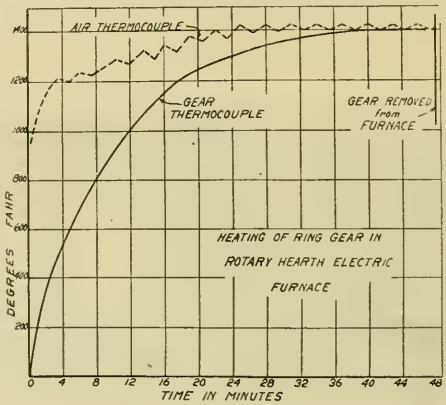

Fig. 3. Time-temperature curve of ring gears heat treated in rotary hearth electric furnace. The solid line shows the temperature of the gear with thermocouple in contact with it. The broken line shows the temperature of the furnace when a thermocouple was placed a few inches from the gear.

pounds being heated in that time. The cost of oil used in heating this same gear is approximately $.005 or about 1/5 of the cost for electricity. To offset this increased cost of electricity we have the reduction of rejections and lower cost of subsequent operations.

While the reduction of rejected gears due to warping has been very greatly reduced, figures as to the number are not available; however, it has been possible to treat the gears in the electric furnace, so as to have an eccentricity of approximately half of the limits set for oil furnace practice, and limits which it was found difficult to meet with oil treated gears. The cost of subsequent operations was reduced approximately $.05 per gear, or an amount equal to twice the total cost of electricity for heating.

The higher cost of the improved heat source, in every case cited, has thus been justified on the basis of the quality of the finished product, as it is reflected in the reduction of rejections, lower cost of subsequent operations, and longer life of product, any one of which, will, in most cases, many times offset the increased cost of the improved heat source.

The features of the electrically heated furnace of the metallic resistor type, which make possible this improvement in quality are:

1. Low temperature of heat source.
2. Accurate and reliable automatic temperature control.
3. Uniform and unvarying temperature distribution.
4. Absence of severe oxidizing and corroding action common to some fuel fired furnaces.

The large area of the heat source, permits it to operate at a temperature

only slightly higher than the temperature of the parts being treated, and renders overheating of any part impossible. In the fuel fired furnace except where a muffle is used, the heat source or flame is several hundred degrees hotter than the work. With these high temperatures of heat source, there is always danger of overheating portions of the charge, especially parts having thin sections. This overheating results in distortion and excessive scaling of the parts.

Automatic control of temperature insures constant conditions in the furnace, and makes possible the duplication of results from day to day. A

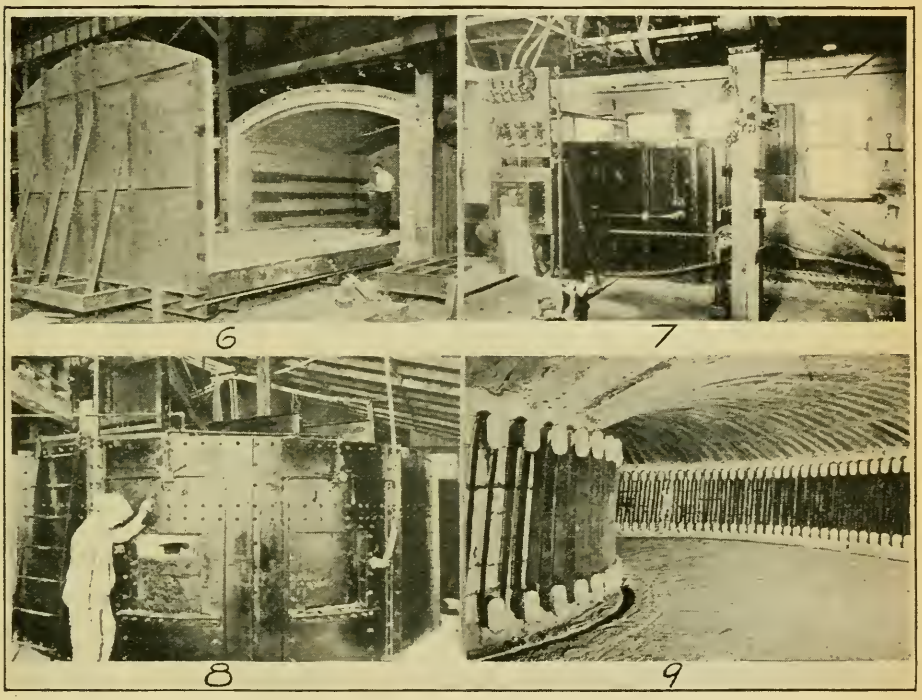

Fig. 6 Resistor type electric furnace used for annealing large iron castings. This furnace it will be noted is of the car bottom type.

Fig. 7 Resistor type electric furnace having a water sealed conveyor. This furnace is used for bright annealing nickel silver blanks.

Fig. 8 Exterior of a large rotating hearth furnace being used in an automobile factory for the heat treatment of cam shafts connecting rods, front and rear axles, steering knuckles, etc.

Fig. 9 Interior of the rotating hearth furnace shown in Fig. 8. The arrangement of the metallic resistors is clearly shown.

temperature control chart is plotted each day. Regular runs with such a furnace show a maximum temperature variation of about 5 degrees Fahr. plus or minus in the air of furnace. This is the variation of air temperature, and since the air changes temperature much more rapidly than the charge, it will be apparent how accurately the temperature of the charge is maintained.

Fig. 3 is the time-temperature curve of gears treated in a rotary furnace similar to Fig. 2. Sensitive thermocouples were attached to a test gear, which was placed in the furnace among the others in regular production. The "gear" thermocouple was embedded in the body of the gear itself, and the "air" couple was located a few inches above the gear. The curve is copied direct from the chart made by recording instruments. It will be observed how

accurately the temperature of the gear is held at 1400 degrees Fahr. up to the time it reaches the discharge door. It will also be observed that fairly wide changes of air temperature caused by throwing the power on and off, caused no appreciable change in the temperature of the gear.

This curve also illustrates another point; the uniform temperature that it is possible to obtain in a furnace of the metallic resistor type. In this furnace the windings are all on one circuit, and yet it is possible to maintain, by a proper distribution of the windings, a uniform temperature up to a point directly in front of the discharge door. The heating of a charge under these conditions insures uniform heating. In uniform heating, distortion and

Table I

Over-All Cost in Producing Typical Heat Treated Components

Item	Part	Operation	Factory Cost	Cost of Heat Treating	Cost of Elec. for Heat Treating	Electricity in % of total Cost
1	Segment Combination Die	Harden & Draw	$1380.00	$13.50	$4.16	.3
2	Combination Die	Harden & Draw	1138.00	12.00	3.70	.32
3	Round Blanking Die	Harden & Draw	638.00	5.03	1.50	.23
4	Segment Blanking Die	Harden & Draw	782.00	9.45	2.92	.37
5	Die	Harden & Draw	795.00	10.53	3.43	.43
6	Die	Harden & Draw	875.00	8.66	2.67	.3
7	Gear	Harden & Draw	234.00	13.00	3.70	1.5
8	Gear	Harden & Draw	263.00	15.00	4.44	1.7
9	Gear	Harden & Draw	338.00	21.00	6.25	1.8
10	Gear	Harden & Draw	391.00	26.00	7.60	1.9
11	Gear	Harden & Draw	455.00	30.00	9.06	2.0
12	Die block	Harden & Draw	110.00	1.75	.65	.6
13	Gear	Harden	5.00 (estimated)		.0286	.006

internal stresses are reduced to a minimum, and the quality of the heat treated part improved. This will manifest itself both in reduction in rejections and increased life of product.

In the electric furnace ideal atmospheric conditions exist for heat treatment, with the result that heat treated parts are practically free from pitting and scaling. This reduced scaling and pitting reduces the cost of subsequent operations in cleaning the dies and gears previously referred to.

Even in the face of the large savings that can be effected thru the use of the electric furnaces, as shown in the foregoing, their adoption has been delayed by difficulties in producing a dependable and reliable furnace. The use of early furnaces was fraught with all manner of difficulties. The frequent shut downs and costly repairs dampened the enthusiasm of the most ardent followers. It was only in recent years, under the stress of war time demands, that a type of furnace was evolved that could compete with the fuel fired furnaces on the basis of dependability.

The first furnaces of this type were built for heat treating gun tubes and jackets. Fig. 4 shows the general construction. This form of construction of heating units is extremely flexible in its application, and can be mounted in practically all types of furnaces used for the heat treatment of steel.

Data is at hand relative to a car bottom furnace used for annealing steel castings with 1500 pounds per charge. This furnace has been in operation

for 18 months. The cost of operation is approximately the same as for the oil fired furnace. The quality of the product shows decided improvement over the oil fired product.

Fig. 5 is a recuperative furnace used for annealing steel wire. The charge after being heated to the annealing temperature is placed in the cooling chamber where it imparts its heat to the incoming cold charge. Thirty eight tons of wire have been annealed in this furnace in one day of twenty four hours. The furnace has been in continuous operation one year.

The furnace shown in Fig. 6 is used for annealing large iron castings. A sixty ton charge is annealed at a temperature of 550 degrees Cent. with a temperature distribution of plus or minus 5 degrees Cent. throughout the furnace chamber.

Fig. 7 is a water sealed conveyor furnace for bright annealing nickel silver blanks. It has a capacity of approximately 1200 pounds per hour.

Figs. 8 and 9 are exterior and interior views of a large rotating hearth furnace installed in an automobile factory. The hearth is annular shaped 5 feet wide (5 feet inside diameter, 15 feet outside diameter.) During the day about 2700 pounds of cam shafts, connecting rods, front and rear axles, knuckles, gear blanks, etc. are put through per hour for hardening or annealing and the furnace is used for carbonizing at night.

Three years operation of a large number of furnaces of this construction have earned them the right to be considered in a class with the best of fuel fired furnaces, from the standpoint of dependability and for continuity of service.

The problem confronting anyone in the choice of steel treating furnaces is thus chiefly the problem of determining the effect of the various furnaces on the over-all cost of the heat treated part. A careful analysis along the lines outlined in this paper may in many cases reveal that furnace operating costs are of secondary importance. After three years of experience in the use of electric furnaces for steel treating in large scale production it is safe to predict that in the majority of cases where a high grade product is required, the lowest over-all costs will be obtained through the use of electric furnaces.

WHAT IS STEEL

By John A. Mathews

THE officers of the New York chapter of the American Society for Steel Treating, I understand, have decided to cover in a fairly systematic way the metallurgy of steel in the various meetings this winter, rather than to depend upon papers of a miscellaneous nature such as have been heretofore presented. It seems to me that this should be a valuable and instructive course and I am convinced of the wisdom of the officers in outlining such a program, but I am not convinced that they made a wise choice in their first speaker.

However, if it is proposed to discuss metallurgy in a fairly comprehensive way, it is wise to begin with the fundamentals and lay a sound foundation upon which to build later in the winter.

In connection with the use of English, we have authorities who tell us from time to time what constitutes good usage, and what is the correct use of words. We have a committee on simplified spelling composed of distinguished scholars, who from time to time, publish a list stating what words we may misspell with impunity. We all recall words that a few years ago were considered as slang, or at least, as not quite right for dignified conversation, but which have now become adopted into the language and seem to have the sanction of good usage on the part of writers and speakers of note. I believe I recall one eminent professor who has passed upon the expression "it is me," but unfortunately at the moment I do not recall whether he said that this was good usage or not. The point I want to bring out however, is, that preciseness of thought will lead to preciseness of expression, and it will clarify our ideas and prevent misunderstandings, if when we talk about iron and steel, we all mean the same thing by the same words.

When I was a boy, I had a very thorough training in the Westminster shorter catechism. I never knew just why it was called the shorter catechism, for it consisted of over one hundred questions and answers, to a considerable extent, definitions. I never inquired what the longer one was like. However, I did know the shorter one forward and backward, and I recall the concise definition of sin. The difference between sin and steel is that our ideas on the former have remained fairly well fixed during the two hundred fifty and more years since these eminent theologians defined it, whereas our ideas in regard to steel have undergone radical changes during that period, as the processes of manufacturing it have changed.

Prior to 1740 practically all steel was made by the cementation process from wrought iron. In 1740 came the Huntsman process for the manufacture of crucible cast steel, and from that time to this, many others processes have been invented, many improvements have been made, and our ideas pertaining to this substance have undergone changes. But, before we discuss steel, a few words on iron are in order.

The word *iron* is used loosely by the general public, and sometimes by technically trained men to represent a great variety of materials differing widely from one another. First, iron means the chemical element *ferrum* represented by the symbol *Fe*. The pure chemist in speaking of iron would probably mean the chemical element. We also speak of iron meaning the wrought iron product, more or less fibrous in structure, and containing a considerable

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A paper presented before the New York chapter. The author, Dr. John A. Mathews, is President of the Crucible Steel Co. of America.

quantity of slag. It is sometimes produced directly from the ore, and sometimes from another variety of iron, namely, pig iron and cast iron. The word iron is sometimes loosely used in speaking of iron ore, as for instance, it might be said that there was a great deal of iron in the state of Michigan, or that the iron carried on the Great Lakes was 30 million tons per annum. In this usage no intelligent man would be misled but it would be clearly understood that the ore, the oxide of the iron, rather than the metallic iron was meant, but the distinction between wrought iron and cast iron is not always clearly made in conversation and writing, and sometimes one has to inquire as to what particular variety of iron is referred to. *Steel* itself, is as much a variety of iron as is pig iron and wrought iron. In fact, it is made from wrought iron by carbonizing and from pig iron by decarbonizing. Is it possible then to draft a precise definition defining exactly what steel is? What are the essential features which the material must possess?

In my library, I have a collection of metallurgical books dating from 1540 down to the present time. In examining many of them I fail to find any explicit definitions of *steel*. For instance, in an essay on "Metallick Words" by Sir John Pettus, published in 1683, we have a glossary of principal metallurgical terms of his day, but under *steel* I do not find a definition. All that he says is, "Now this and all other sorts of iron are by Pliny comprehended under the word *stricturae*, and he saith that the goodness of the steel ariseth from the goodness of the iron mine from which it comes with the assistance of waters and various quenchings of it in waters and oyls," to which he adds, " 'Tis wonderful that man's blood should have such virtue in it as to be revenged on the iron blade that shed it, being once embrewed therein, it is given ever after to rust and canker." This quotation is of interest because it points to the very early knowledge of steel by the Latin writers and it shows that hardening in both water and oil was known at that early time; and in view of the fact that there was no chemical knowledge of refining and purification of the iron ores at that time, the merit of the products of such mines rested on the quality of the ore therein contained. This was true down to the very modern times, in fact, down to the invention of the basic process.

In the early colonial days of our own country, and extending down to the beginning of the last century, small plants were started to make tool steel. Usually they drew on the local ores and usually the plants were of short duration, because of the fact that the local ores did not produce iron of suitable quality for tools. The only way that the manufacturers could determine this at that time was by actual trial to discover whether ores were of high grade or not, as even chemical analysis was not used as a routine method in iron production of 50 years ago. The fine steel industry of France never made much progress until very recent years, and for this Reamur was largely responsible. He was the pioneer metallurgist in the early 1700's and in fact, was the pre-eminent man in this line in his time. He went on record to the effect that good steel could be produced from the local ores of France and the Government for many years would subsidize the steel industry which would undertake to produce their products from local ores. At the same time, England and Germany recognized that certain ores were much superior to others, and that the ores of Sweden were the best in the world. England, therefore, built up a great reputation for fine steel based upon the use of Swedish raw materials, as did also Germany, while the Austrian ore

posits in certain districts were of very high order and served as the basis for a substantial fine steel industry.

Therefore, from Pliny's time down to almost the beginning of our own generation, the chance selection of an ore determined whether or not a steel enterprise would be a success, and only after long experience, certain ores were demonstrated to be good, while others were not good. But the reason why they were not good was not thoroughly understood, because chemical analysis and other methods of investigation were not available to the early iron makers.

But to return to the matter of a definition. I have searched the works of many others from Sir John Pettus down to the present day, and I can find whole volumes written about iron and steel, but without an attempt anywhere in them to define what they are. By many, the capacity for hardening in water has been considered as the distinguishing characteristic of steel. By others, it is considered that the preparation of this form of iron by a melting process is essential to distinguish steel from the other forms of iron, the result of melting the raw materials being largely to free them from slag and inclusions which are characteristic of wrought iron. The third quality generally considered as necessary is that of malleability. This distinguishes steel from cast iron. It is my opinion that the two really essential characteristics are: First, manufacture by melting, second, the quality of malleability. It does not seem to me that the property of hardening should be considered as essential for the definition. There was a question discussed a few years ago as to whether the name *ingot iron* was the proper one to describe a well known American product. In my opinion this should be called *ingot steel.* It is extremely low in carbon and will not harden in the ordinary sense of the word by quenching in water. Nevertheless, it is manufactured by melting in the Open-Hearth furnace and results in a product which is malleable. It is free from slag and inclusions, and therefore, should not be called iron, thereby likening it to wrought iron which has not been produced by a melting process, which is not free from slag and inclusions, but which is of course, malleable. The matter of hardening is a question of degree and the degree of hardening increases directly with the carbon content. While a steel extremely low in carbon does not harden to a very material degree as measured by the scleroscope and Brinell test, nevertheless, such carbon as it possesses may be converted into the martensitic state by heating to a high temperature followed by quick cooling. It may therefore, be said to have been hardened, even though the physical hardness may not be materially increased, owing to the small amount of carbon. The operation however, will convert such carbon as it possesses into martensitic form which is the form that characterizes hardened steel, but the small amount of martensite is contaminated with so much free ferrite, which does not harden, that the final product will be physically soft.

In my opinion, steel as we now know it, the steel of commerce, whether made in Bessemer, open-hearth, crucible or electric furnaces is that form of iron which has been produced by melting to yield a finished product which is malleable. The question of carbon content and incidental presence of other elements is not vital to the definition. When we wish to refer to steel of bygone centuries prior to the invention of crucible cast steel we may still use the term steel, prefixed by cemented, blister, shear or double shear. These forms of steel did not disappear entirely by any means with the invention of the crucible process, but continue at a diminishing rate of production down to the present time. Their amount is so small, however, that when it is necessary

to refer to them the qualifying words should be used to indicate that the materials are essentially different from the steels of today.

We notice how successfully Sir John Pettus sidestepped any attempt to define steel in a book which was supposed to be a glossary and dictionary of technical terms of his time. However, the question of defining it in his time was much simpler than at present. The only material known as steel was cemented steel made from wrought iron that had been carbonized, and the finer grades were made by faggotting such carbonized wrought iron followed by welding and working down to smaller sizes giving the product known as shear steel, and this was sometimes re-faggotted, welded, and worked down a second time giving material known as double shear steel, and by this process of fagotting and welding, the alternate layers of high and low carbon steel had some opportunity to equalize by diffusion and were drawn out into thinner bands by the reworking, so that the finished product, in the case of the double shear steel was made up of relatively thin bands of high and low carbon steel which answered very well in its time for the production of tools of various kinds. It might be mentioned in passing that there had been produced in India from the very earliest times a fused product which was high in carbon made by melting down soft iron with carbonaceous material. This was the product known as Wootz Metal, but while its manufacture continued to a very small extent over many centuries of time yet the product was so difficult to forge and handle that it never made any impression on the industrial world, and was practically disregarded except as a curiosity, and the first steel that attracted attention and revolutionized the industry was the crucible cast steel of Huntsman in Sheffield about 1740. The Wootz Metal was melted in clay retorts and was allowed to cool in the furnace. It was, therefore, not cast steel. The principal difficulty which Huntsman had to contend with in perfecting his process, was in the producing of crucibles which would stand the high temperatures necessary for melting the wrought iron or converted bar iron. After he had succeeded in procuring the crucibles, there was little difficulty in the production of the first cast steel. Huntsman, however, in his first experiments, allowed the steel to cool in the crucibles which were later broken away and the resulting mass used as an ingot. Just when he began to pour the metal from the crucibles into a mold, I do not know.

Steel, then, as we know it today, began with Huntsman's invention, that is, the invention of cast steel made by a process of fusing, thereby eliminating slag and producing a product practically homogeneous in which the carbon and other elements were uniformly distributed through all portions of the product. The product was also malleable, and therefore, within the definition of steel based upon fusion and malleability. Steel prior to this time, was produced without fusion, by the process of carbonizing wrought iron.

We have used the word 'carbonize' several times and this brings up the question as to the use of the word *carbonize* versus *carburize*. I am inclined to think that some of our metallurgists have passed upon this use of words, and in general prefer the word *carburize* to indicate the process of adding carbon to low carbon iron or steel products. It seems to me that both words may be used to convey a definite distinction in regard to their usage. I am inclined to use the word *carburize* in connection with the process of adding carbon to the molten products of open-hearth, electric or Bessemer furnaces. Carbon is added to molten steel in the form of anthracite coal, charcoal, ferromanganese, etc. Sometimes the process is carried out in the furnaces and sometimes in the ladles, and this process it seems to me, might be covered by

the word *carburize*, while the process of adding carbon to solid steel as in the case-hardening operations, I am disposed to call *carbonizing*. Therefore, the old process of making a cemented steel would be considered a carbonizing process in which the bars of wrought iron were packed in charcoal and subjected to heat in furnaces looking more or less like pottery kilns for a period of 7 to 12 days. The same word would apply to the modern practice of case-hardening small finished parts, as gears, in which the finished parts are packed in various mixtures (with which the market is flooded) followed by heating in closed boxes, by means of which operation the carbon passes into the surface of the steel. The principal factors by which the case-hardening process is controlled, are time and temperature, and the raw material used in imparting the carbon. By the proper control of these elements we regulate the depth of case and maximum carbon content in the most highly carbonized zone, and to some extent we regulate the gradation of carbon from the outer high carbon zone to the inner soft carbon zone, and also to a certain degree, determine whether there shall be a sudden or gradual change from the hard to the soft parts.

It has been recognized for nearly 150 years that carbon is the element which confers on iron its wide variety of properties. When in definitions of steel, carbon is included as an essential, it is generally stated that the carbon content may vary from 0.10 to 2.00 or 2.25 per cent. The ordinary steel of commerce is well within these ranges and seldom exceeds in practice 1.50 per cent in the case of certain tool steels. The true upper limit, however, is the limit of forgeability, and this depends largely upon the skill of the one doing the forging. Plain carbon steels containing as high as 2.50 per cent carbon can be forged with difficulty, and many of the wire drawing dies or Wortle plates as they are sometimes called, contain over 2.00 per cent carbon, and I suppose that the theory of this use lies in the fact that the excess carbon exists in the form of cementite which is extremely hard, while the matrix is much softer pearlite, and presumably the cementite particles act to resist the abrasive action of the wire during the process of drawing. The principal difficulty in forging the extremely high carbon steels arises from the tendency of the excess cementite to break down into ferrite plus free graphitic carbon. Certain elements tend to keep the carbon in combination and certain other elements tend to precipitate the free carbon in high carbon steels. Manganese and chromium are the principal elements which tend to keep it in combination, while silicon and nickel tend to precipitate free carbon. When it comes to a matter of carbonizing steel the same elements act the same way. High chromium and manganese seem to facilitate the absorption of carbon while silicon and nickel tend to retard the absorption of carbon.

In addition to the iron and carbon present in all commercial steels, there are four other elements ordinarily present whose effects must be considered. They are manganese, phosphorus, sulphur and silicon. These are often considered as impurities since it is almost impossible to make steel free from them. The first two elements, however, especially manganese, must be considered essential and beneficial, while phosphorus and sulphur are nearly always undesirable. Copper and arsenic are usually present in minute quantities and in amounts ordinarily present, their effects are negligible. Aluminum is not normally present for the reason that it cannot be eliminated, but because it is added to the steel during casting and traces of it may be found in the finished product. Ordinary steel, then, by whatever process made, may contain carbon and manganese from 0.10 to 1.50 per cent; silicon from trace to 0.25

per cent; phosphorus and sulphur from below 0.01 to 0.10 per cent; with copper, aluminum and arsenic in negligible quantities. Steel usually contains hydrogen, oxygen, nitrogen, and cyanides in minute quantities, which are not readily determined. Nevertheless, we must assume that each and all of these elements exert some influence in regard to the final quality of the steel. We have much to learn as to just how they act and as to what this influence is, particularly in regard to tool steel. It so often happens that two samples of steel, of practically identical analyses as far as ordinary elements are determined, give such different service that we are forced to the conclusion that there are other factors than those which our present methods of investigation deal with, which control ultimate quality. This mysterious something called quality, is frequently called by the British, *body*. Just what body is, I have never seen defined. Probably it goes back to the original statement referred to in the early part of this paper by Pliny; i. e., to the mine itself, in which the ore is produced. Steels coming within the limits of analysis just mentioned serve an enormous number of purposes and in a certain sense that particular analysis which yields a steel suitable for rails, springs, knives, drills, and gun barrels, may be considered a special steel. Such is not the commonly accepted significance of the term special or alloy steel, although as has been seen, all steel is an alloy. By common consent, we consider it almost as though it were a chemical element, as though it were a simple substance instead of an alloy of from two to ten constituents. When we materially exceed the limits of the analysis already given, or when we add to ordinary steel other elements not normally present, for example; nickel, chromium, vanadium, or molybdenum either by intention or chance, the product is an alloy or special steel. When one of the normal constituents, silicon or manganese is greatly increased in quantity, it becomes difficult to decide arbitrarily the percentage at which we pass from regular carbon steel to an alloy steel. Abnormally raising the ordinary constituents, so alter the properties of the resulting alloy that many useful purposes are served and results not otherwise obtainable are secured. We thus see why the term alloy steel has acquired a special significance meaning any steel to which in addition to carbon and iron and impurities common to all steel, other metals or metalloids have been purposely added to change or improve its natural properties. Chemically pure iron may properly be classed among the rare metals.

Not only is steel a very complex material, but its complexity is further increased by the allotropic character of the element iron and by the fact that carbon may exist in several different chemical combinations, while the same is probably true of sulphur and phosphorus. In cooling pure iron from the molten condition, we find its freezing point at about 1500 degrees Cent. All of its alloys with carbon up to 4.3 per cent melt at decreasing temperatures down to 1130 degrees Cent. Below the initial solidifying of pure iron, there are two other temperatures at which cooling momentarily stops. These temperatures are 895 degrees Cent. designated as Ar_3, and at 765 degrees Cent. designated as Ar_2. When carbon is present, a third very marked arresting of cooling occurs at 690 degrees Cent., known as Ar_1, the ordinary recalescence point.

It is believed by many that the molecular transformation occurring at Ar_2 and Ar_3 indicated allotropic changes in the iron itself. At temperatures above Ar_3 we recognize the gamma-iron of Osmond, nonmagnetic and solvent for both elemental carbon and carbide. Between Ar_3 and Ar_2 points, iron exists in the condition known as beta-iron, also nonmagetic but not a solvent

for free or combined carbon. Below Ar_2 iron exists in its magnetic condition known as alpha-iron in which iron carbide is not dissolved, or only slightly.

There are many who do not accept the allotropic theory, but whatever significance these critical points may have, all concede that they do occur and that at certain critical temperatures the character of the iron undergoes profound changes. Those who do not admit the allotropy of iron neither dispute the allotropy of carbon nor its occurrence in iron in at least two conditions: First, as free graphite; second, as combined iron carbide, and it is generally supposed that this combined carbon may exist in steel as either isolated particles or in a dissolved state.

In general, it may be said that the influence of other elements upon iron-carbon alloy is:

1. To change the temperature of the occurrence of the critical points.
2. To modify the condition in which the carbon occurs.
3. To remove occluded gaseous impurities.
4. To combine chemically with the iron or carbon, or both.
5. Either combined or free to form iso-morphous solutions with the iron or to separate into distinct microscopic particles.

In thus deporting themselves these elements are found to improve or injure the steel, to make it harder or stronger, ductile or brittle, a better magnet or a better tool. The effect of these additions have been the subject of long and careful study, but the exact manner in which the added elements influence the iron carbon system so as to produce new and useful properties in steel is not yet perfectly understood.

Notwithstanding its complexity, steel and its alloys follow in many cases the general laws of physical chemistry which have been found to hold good for simpler and purer alloys, these laws being the laws of solution. Roberts-Austen and Spring found that one metal diffuses into another like salt into water. In general, solubility increases with the temperature. Metals and alloys will flow under pressure. Alloys may or may not react when brought into intimate association by fusion or pressure. Molecular mobility increases with the temperature. Upon cooling of molten alloys, phenomena suggestive of freezing salt solutions are observed. The depression of the freezing point of a metal when another is added to it follows the laws of Coppet and Raoult for dilute solutions, and generally the phase rule of Gibb applies quite as well to the explanation of conditions of equilibrium in alloys as to similar problems in regard to liquid solutions.

It has been found as a result of the work of a number of investigators that the electrical conductivity of iron, as well as other alloys, is a function of the atomic weight of the added element so long as it dissolves in the principal metal to form a true solid solution.

It has been intimated, iron has been known from the earliest days of civilization. The art of carbonizing and hardening it probably antedates the Christian era. Cast iron and foundry practice dated from about 1400, and within a few years the crucible melting process will round out its second century. Notwithstanding this, all of us, especially the younger men who are just getting their first practical acquaintance with the handling of steel, are apt to overlook the fact that the present steel era is of very recent date: i. e., the steel for ordinary structural purposes, for rails, for ships, and for immense forgings for ordnance, machine construction and other purposes. This development has all come about within our own generation. We may almost say

that the age of steel in the United States began with the development of the basic open-hearth process about 1888. Bessemer steel had been produced much earlier while blast furnaces and foundries had been in existence in the country from the early colonial days, and in fact at one time iron was exported from this country to England, and its production in this country was stimulated by England. The production of various forms of iron in the early days was largely based upon the rule of thumb method, experience and knowledge passed on from father to son. Chemical methods were seldom applied, and in fact, the suggested introduction of such methods met with strong opposition on the part of the so-called practical steel makers. The laboratory chemist was not welcome, and has only been considered a necessary part of an iron or steel works for the last 40 or 50 years. The microscope and pyrometer were of much more recent adoption, and each in its turn met with opposition from the steel makers, and its benefits were scoffed at by the old time steel men. With the adoption of all of these additions which we have today, we must recognize that the making of steel is not an exact science. It is rather an art, to which scientific methods may be applied, but in its fundamental operations it still remains a handcraft industry, aided and guided by scientific control methods. Our young metallurgists are apt to become impatient because the steel cannot always do the impossible, and because the steel makers cannot manufacture their product 100 per cent perfect. This is the ideal for which conscientious manufacturers strive but which can never be perfectly attained.

To further illustrate the extent of recent progress, let me recall to your minds the state of the art and kindred arts just 100 years ago. Peter Barlow, a professor in England, published an essay on "Strength of Timbers and Other Materials." This seems to have been the beginning of the study of physical properties of engineering materials. His experiments included the study of iron and its properties with reference to design of bridges. The first American sheet rolling mills were built in 1818. Mill shafting was introduced in a mill in Manchester, by William Fairbairn, the shafting all being turned by foot lathes which permitted of higher factory speeds; size of shafts and pulleys were reduced. This brought about a revolution in power transmission as the shaftings prior to this time were made square, often of timbers, and fly and gear wheels were secured in place with wooden wedges. The first coke pig iron was produced in America in 1819 although it had been produced much earlier in England, and the first attempts in America with the use of raw bituminous coal in a blast furnace were made in the same year. The daily production of the Krupp Works at Essen was about 400 pounds of crucible steel. In 1820, the production of pig iron in America was about 20,000 tons.

A matter of very great interest to metallurgists is that in 1820, or just a century ago, alloys of iron and chromium were prepared by Derthier, and alloys of iron and nickel, chromium and some other rare metals were prepared by Michael Faraday. So far as we know, this is the beginning of alloy steels. Nevertheless, the commercial production of them did not begin until much later. So far as I have been able to learn, the production of Mushet air-hardening tool steel furnished the first instance of alloy steel used in the industry. This was about 65 years ago. In 1820, also, the first wrought-iron rail rolling mill was started in England and the manufacture of rolled boiler plates seems to have been started at about this time by Dr. Charles Lukens in the Brandywine Rolling Mill, and this industry, as you know, is still in existence under the name of the Lukens Iron & Steel Company. These plates

were rolled charcoal iron blooms. Peter Barlow made the first experimental investigation in regard to the phenomena of induced magnetism and perfected methods of adjusting ships' compasses by fixing small iron plates in position to compensate for various magnetic disturbances. It is interesting to note that experiments made by Faraday on alloy steels already referred to, were made for the purpose of,—first, making better cutting tools, and second, securing material that would be superior for reflectors, and while Faraday employed chromium in his experiments, it is interesting to note that we had to wait almost a century for the perfection of stainless steel which is a chromium alloy, and which may be used for the manufacture of metallic reflectors, which will not tarnish. Oersted, a Danish scientist, discovered electromagnetism. Seebeck, a German physicist, discovered thermo-electricity and that current produced by heating two metals in contact increased with the temperature. This principle, however, was not applied to pyrometry until 1886. Faraday, also, pointed out the difference between annealed steel and hardened steel, showing that the hard steel dissolved completely in hydrochloric acid, while the annealed steel leaves a residue which he called carburet of iron. Barlow was continuing his work in induced magnetism and studied the effects of varying temperatures on the magnetic power of iron, and finally we might mention that the Rensselaer Polytechnic Institute was founded in 1824 to give instruction in "the application of science to the common purposes of life." It is the oldest engineering school except West Point in any English speaking country. These events of a century ago will help to impress upon your minds the remarkable progress that has been made in science, particularly as pertaining to iron and steel within that period, but its greatest advancements have been made within the present generation since steel became a tonnage commodity of such vital importance to the industrial life of every civilized nation.

In the field of iron and steel production, research has yielded most valuable results, and these progressive manufacturers who have recognized its importance, have profited much thereby. It should not be overlooked that the purpose of research in industry, like every other department in industry, is to increase profits. Manufacturing concerns exist for the making of profits and legitimate manufacturing profits in any company are the rewards that the public pays for service rendered or risk taken. The desire for profits is the impelling motive that leads manufacturers to take risks and build up industries that give employment to others. The research department of a steel company may function in many ways to contribute its part to the general success. Its first efforts should be to improve the product. Success in this direction leads to a greater demand, large output, greater ability to meet competition, and ability to command higher prices for the product. The research department should direct its efforts toward lowering costs:

1. By finding cheaper but satisfactory raw materials.
2. By improving old processes and developing new processes to increase the yield or decrease labor, or both.
3. By developing new products and finding uses for by-products.
4. By finding new uses for existing products.
5. By improving operating conditions in the plant not directly connected with the product itself, such as effecting savings in water, fuel, lubrication and electricity, and by improving the working cycles, material movements, and power conditions.

All of these results in public good and bring their reward because they lead to better goods, and the better supplying of public needs.

If it is commendable to make two blades of grass grow where one grew before, how much more worth while is it, to make one pound of steel go where two went before, by improving the quality and treatment, and adopting a metal particularly suited to requirements. Here we have real conservation in raw materials. The higher grades of ore are not believed to be inexhaustible and in making one pound we not only use one half as much ore but also one half as much fuel and refractory material as in making two pounds. Furthermore, if the steel becomes a moving part of a machine, automobile, or airplane, there will be a perpetual saving in motive power during the life of the machine. Sometimes it does not lead so much to conservation as to extension of use, for when such results are achieved more machines, automobiles and airplanes will be built and the maker of the steel will find a wider market.

Research in the steel industry has made possible the automobile and airplane, but we have been inclined to put it the other way, i.e., that the demands of the automobile and airplane produced the advancement of steel. It should be remembered however, that nickel, chromium and chrome-nickel steels all antedate these modern inventions. Dr. W. R. Whitney has well said, "Necessity is not the mother of invention; knowledge and experience are its parents." This is clearly seen in the case of many industrial discoveries. High speed cutting tools were not a necessity which preceded, but an application which followed, the discovery of the properties of tungsten-chromium-iron alloys; so too, the use of titanium in arc lamps, and of vanadium in steel were sequels to the industrial preparation of these metals and not discoveries which came by sheer force of "necessity."

Steel men,—always modest,—have been too modest in claiming their part in the wonderful developments in machine construction due to their efforts in producing steels that permitted of uses which formerly would not have been possible. The Ford car would have cost several times as much as it now does and the Ford plant would have been many times as large as it now is for the same production had it not been for Taylor & White's investigations on "The Art of Cutting Metals," and they probably could not be produced at all in their present design had only plain carbon steels been available.

Metallurgy is defined as the art of extracting metals from their ores, and strictly in accordance with the definition, there are relatively few metallurgists. Most of those who call themselves such, are principally interested in the metal after it had been extracted from the ore. The German term siderology, the science of iron, is deserving of wider adoption. Most so-called metallurgists might be more appropriately called siderologists, but one, who like myself, has graduated from the laboratory into executive duties, might then be called a "considerologist." After all, the contemplative side of science is important and while of routine testing we have done a great deal, we have been too busy to analyze results and draw conclusions and search hidden facts and relationships. Possibly this is to be expected in a relatively new country with abundant raw material and an almost limitless domestic market for its manufactured products. In a new country like ours, we cannot expect the ripe scholarship of England and France. Many of the fundamental laws of science were discovered while we were in our colonial days, and development of a new nation is not compatible with the development of leisurely investigations. Research men, like poets, are born, not made. You can teach research methods, but you cannot provide a research mind. We have difficulty in finding men of the typical research make-up. In my experience, such men have

oftener been found among men of chemical and physical training than among men of engineering training. The great achievements of science and research in the past were not the work of committees, but of individuals. Newton, Davy, and Faraday, by reason of their innate ability and personal qualifications made their great contributions to science, and the greatest advances in basic science have been made in times of peace, and not in times of war. Militarism is fatal to the best scholarship that promotes public welfare and the advancement of civilization.

The writer outlined a program in which a research department may participate to promote the general interests of its industry. Not much exception could be taken to that plan by any board of directors or executives. But, how far shall we extend research into the field of so-called pure science in a money making institution? Here is where a difference of opinion is quite likely to be seen. In my experience, the pure science of today is the applied science tomorrow, and I have been impressed many times with the fact that discoveries of supposedly only theoretical value soon come to be applied to the practical affairs of manufacture. It is not my judgment that the pure science of the steel industry should be left wholly to the college laboratory or the Bureau of Standards, nor do I believe that the practical problems of the industry should be turned over to such institutions. The industry should assume all of its practical problems and most of its theoretical ones.

Research methods in the steel industry have been much extended during recent years, indeed, the general adoption of routine chemical analysis, physical testing, the microscope and pyrometer are all within the memory of men still active in the industry. Fatigue testing, shock and repetitive impact testing, dilatation, conductivity, and magnetic analysis as research methods in quite general use are developments of this century, and we may almost say, of the present decade. No one of these tests tells us all we would like to know about steel. They are mutually supplementary and the more we have of them the better. And with the use of all of them, in the case of steel that fails in service, it is sometimes very difficult to answer the question "Why did it fail?" From the steel makers point of view, in case of failure, the question to which an answer is most necessary is, at what stage of the operation of manufacture, or subsequent treatment, was the damage done? Was it the raw material, the melting or pouring, the blooming or cogging, the rolling or forging, or annealing? Was the steel 100 per cent perfect when it left the works? Was the damage done by the user?

Great strides have been made in investigation and research and many new methods of testing are at hand, but the field is not yet fully covered, and in answer to the question just propounded, we frequently have to answer, "I don't know."

THE TOUGHNESS OF HIGH SPEED STEELS AS AFFECTED BY THEIR HEAT TREATMENT

By Marcus A. Grossmann

THE present paper offers the results of some measurements of toughness on hardened high speed steels, of two fairly common analyses. The steels were of an 18 per cent and a 13 per cent tungsten type. They were hardened at temperatures ranging from 1700 degrees Fahr. to 2250 degrees Fahr. and were tested as quenched and after drawing at various temperatures up to 1100 degrees Fahr. The toughness was measured in an impact machine of the Charpy type, on test pieces that conformed rather closely to the dimensions of the standard Charpy bar, but were unnotched. The toughness, as expressed in foot-pounds absorbed in breaking the test piece showed variation with the heat treatment. The character of this variation was about the same in the two steels, although the absolute values were different in the two cases. As the quenching temperature was increased, the toughness decreased at first rapidly, then more gradually. As the drawing temperature was increased, the toughness increased to a maximum at about 900 degrees Fahr., and then decreased somewhat at 1100 degrees Fahr.

Steel 13, with about 13 per cent tungsten, was made in a crucible heat, the ladle analysis of which is shown below while Steel 18, with about 18 per cent tungsten, was taken from a stock of approximately the following compositions as shown.

	Steel No. 13	Steel No. 18
Tungsten	12.97 per cent	18.00 per cent
Carbon	0.85 "	0.65 "
Manganese	0.25 "	0.25 "
Phosphorus	0.025 "	0.03 "
Sulphur	0.036 "	0.03 "
Silicon	0.08 "	0.25 "
Chromium	2.81 "	4.00 "
Vanadium	0.20 "	1.00 "

The steel was hammer-cogged from a 5 inch ingot to a 1¾ inch square billet and rolled to ⅜ inch square finished bars.

The test pieces were cut from annealed bars by means of a carborundum high speed cutting-off wheel, they were ground to length, and were then heat treated as follows: After a preliminary warming to about 250 degrees Fahr., the pieces were heated for about 10 to 15 minutes in a preheating furnace at about 1550 degrees Fahr., then transferred to the high temperature furnace where they were held only until they had reached the temperature of the furnace (about 3 minutes for the lowest temperatures, 50 seconds to 1 minute for the highest). They were then quenched in quenching oil. Those to be drawn at 350 degrees Fahr. were drawn in oil; the drawings at the higher temperature were carried out in a bath of molten potassium-sodium nitrate.

Steel 18 was hardened at 1710, 1880, 2020, 2110 and 2230 degrees Fahr., the temperatures varying plus and minus 15 degrees Fahr. in the course of the heat treatments. For each hardening temperature one series of

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A paper presented by Marcus A. Grossman. The author is metallurgist, Electric Alloy Steel Co., Charleroi, Pa.

steels was left as quenched, and one series drawn at each of the following temperatures: 350, 640, 880 and 1100 degrees Fahr, varying plus and minus 5 degrees Fahr.

Steel 13 was heat treated in a manner exactly similar to that of steel 18. The quenching temperatures were 1725, 1850, 2000, 2100 and 2230 degrees Fahr. The drawing temperatures were 340, 660, 900 and 1100 degrees Fahr., with about the same degree of constancy as in the previous case.

The test pieces were not notched. The dimensions conformed rather closely to the standard Charpy bar. With a view to using a size more readily available commercially than is the 10 millimeter square cross section, it was decided to use ⅜ inch square bars throughout these tests. This is of course 0.019 inch smaller than the 10 millimeter size. The test piece was made the standard 55 millimeter length (2.17 inches), and the testing machine was the standard 40 millimeter between supports (1.57 inches). The pieces were heat treated without previous machining.

The pieces were tested in an impact machine of the Charpy type, designed and calculated by the present author to conform rather closely to the Charpy machine. The constants of the machine are as follows:

Total weight of striking arm	19.7 pounds
Distance from axis of rotation to center of percussion	3.75 feet
Distance from axis of rotation to center of gravity	3.22 feet
Capacity of machine as installed	about 80 foot pounds

After the test pieces were heat treated, they were ground smooth on two opposite sides and placed in the testing machine so that a ground surface was in contact with the vertical supporting edges, and the other ground surface presented to the striking edge.

The results obtained with steel 18 are given in Table I, which gives in each case the average of all the tests for that particular heat treatment. The number in parentheses indicates the number of tests from which the average was calculated. The average is a direct numerical average and is not a weighted mean. These impact values (energy absorbed in breaking) were very far from being uniform for a particular heat treatment, and while in general the average of 5 or 6 tests would be fairly constant, a single reading was apt to be very misleading. The following series, quenched at 2230 degrees Fahr., with no draw, is a good example of the maximum uniformity obtainable. On the other hand the series, quenched at 2230 degrees Fahr. and drawn at 880 degrees Fahr., shows the variation liable to occur:

Foot Pounds	Foot Pounds
2.6	4.0
4.8	11.8
5.2	9.0
4.8	4.1
4.0	
4.6	
6.9	
Average 4.7	Average 7.2

It is believed that very close control of the rate of heating will lead to much more concordant results. The effect of the rate of heating is still under investigation and cannot yet be reported on.

In Fig. 1, the foot pounds are plotted against quenching temperatures, each curve representing a particular drawing temperature. The

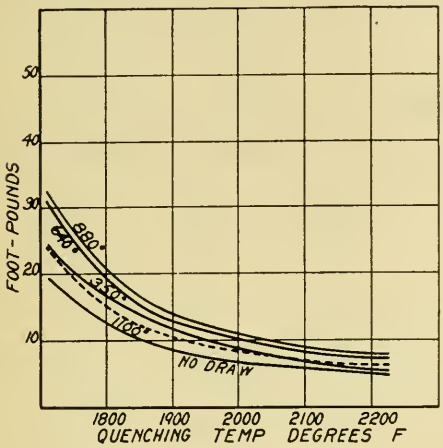

Fig. 1—Impact Values versus Quenching Temperatures 18 per cent Tungsten Steel.

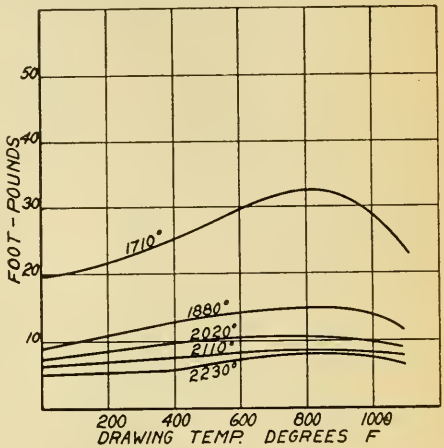

Fig. 2—Impact Values versus Drawing Temperatures 18 per cent Tungsten Steel.

curves are not drawn exactly through all the points given in Table I, as there are a few points off the curves which would confuse their general appearance. All the data available were considered in drawing up the curves shown, and it is believed that they show fairly accurately

Table I

Steel XVIII

Impact test results for various hardening and drawing temperatures

Hardened at Degrees Fahr.	1710	1880	2000	2110	2230
No draw	19.9 (6)	7.1 (5)	7.5 (6)	6.2 (16)	4.8 (19)
Drawn at 350 Degrees Fahr.	24.3 (3)	13.3 (4)	5.8 (9)	5.8 (13)	5.2 (16)
Drawn at 640 Degrees Fahr.	31.1 (5)	13.7 (4)	10.9 (4)	4.0 (4)	7.6 (4)
Drawn at 880 Degrees Fahr.	16.5 (4)	15.0 (4)	10.1 (4)	8.2 (14)	8.0 (14)
Drawn at 1100 Degrees Fahr.	24.4 (4)	11.2 (4)	4.2 (6)	6.7 (9)	6.5 (12)

the average results that may be expected from the heat treatments shown. This method of drawing up the curves was followed throughout. It will be seen that as the quenching temperature was increased, the

toughness decreased fairly rapidly at first, especially with low drawing temperatures. As the quenching temperature was increased still further, the toughness decreased less rapidly.

In Fig. 2 the foot pounds are plotted against drawing temperatures, each curve representing a particular quenching temperature. It will be seen that for each quenching temperature, the toughness increased as

Table II

Steel XIII

Impact test results for various hardening and drawing temperatures

Hardened at Degrees Fahr.	1725	1850	2000	2100	2230
No draw	35.7	8.4	10.9	9.6	11.2
	(6)	(5)	(8)	(10)	(8)
Drawn at 340 Degrees Fahr.	47.0	18.6	10.1	15.6	9.3
	(6)	(5)	(7)	(12)	(8)
Drawn at 660 Degrees Fahr.	51.5	27.8	13.2	7.9	12.8
	(6)	(5)	(5)	(5)	(5)
Drawn at 900 Degrees Fahr.	59.9	33.4	18.7	14.0	11.9
	(6)	(4)	(8)	(10)	(8)
Drawn at 1100 Degrees Fahr.	56.5	18.0	8.6	9.4	7.1
	(6)	(5)	(5)	(5)	(6)

the drawing temperature was increased, up to temperatures of about 900 degrees Fahr. At 1100 degrees Fahr. there was in every case a decrease in toughness, due presumably to the formation of martensite at that temperature. Further increase in the drawing temperature would of

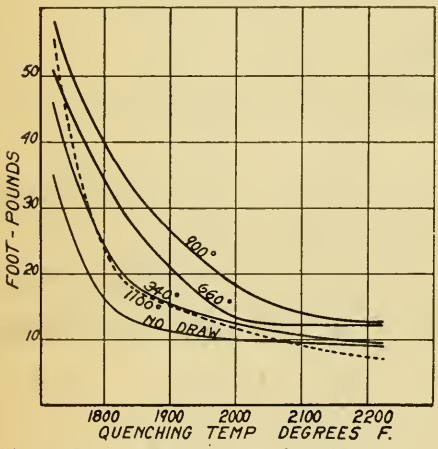

Fig. 3—Impact Values versus Quenching Temperatures 13 per cent Tungsten Steel.

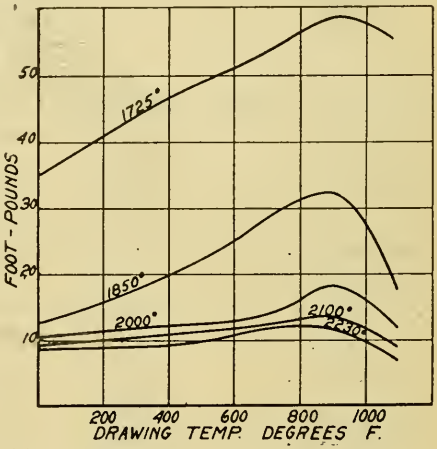

Fig. 4—Impact Values versus Drawing Temperatures 13 per cent Tungsten Steel.

course cause these curves to rise once more when the final annealing effect began.

In the case of steel 13, the general character of the behavior of the steel was about the same as for steel 18. The steel was a much

tougher one, any particular heat treatment giving much higher impact values to steel 13 than the same heat treatment would give to steel 18. This is evident from Table II, which lists the impact figures found for steel 13. These values are plotted in Fig. 3, which shows foot-pounds vs. quenching temperatures, and is comparable with Fig 1. Fig. 4, which is comparable with Fig. 2, shows the foot-pounds plotted against drawing temperatures. The curves are seen to have the same general character as in the case of steel 18, but are placed higher on the scale.

These data, when considered in connection with the hardness, may indicate the heat treatment for particular problems where certain combi-

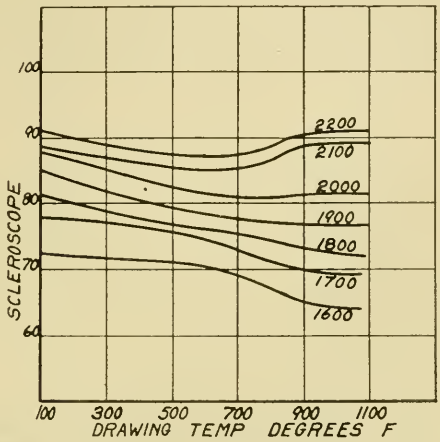

Fig. 5—Scleroscope Hardness versus Drawing Temperatures High Speed Steels.

nations of hardness and toughness are desired. The hardness developed follows in general the curves shown in Fig. 5, which are plotted from data not given here. The character of these is well known, and is given here only for comparison. The secondary hardness begins to show a pronounced development for quenching temperatures above 2000 degrees Fahr. Below this temperature it shows only in that the hardness does not drop further in drawing from 900 to 1100 degrees Fahr. It is of interest to note that the secondary hardness (that is, its accompanying brittleness) shows markedly in the toughness curves for all quenching temperatures.

The author desires to express his appreciation of the co-operation of Mr. Wm. H. Wills, Jr., in the securing of some of the data presented in this paper.

FURNACE ATMOSPHERES AND THEIR RELATION TO THE FORMATION OF SCALE

By George C. McCormick

ABSTRACT OF PAPER

This paper records experimental data and procedure during the investigation of the scaling activity of oxidizing, neutral and reducing atmospheres during the heat treatment of steel. The scale which was formed on low medium and high carbon steels when heated to various temperatures and under varying conditions of furnace atmospheres, has been determined quantitatively. Under certain conditions, oxidizing neutral and reducing atmospheres permit of the formation of scale. This conclusion is supported by the data obtained and may dispel some popular misconceptions.

Purpose of Investigation

A PERUSAL of the available literature on furnace design and operation renders apparent that little or no information has been published which pertains directly to the subject caption. Undoubtedly, much research has been conducted in this field. Believing, however, that the information secured is not widely distributed, the writer assumed the task of investigating the phenomena of scaling under diverse conditions. The results of these investigations are hereinafter reported.

An important chemical property of metallic iron is its tendency to combine with oxygen. Under favorable conditions of atmospheric humidity and temperature, rust, a compound of iron and oxygen, forms with speed and facility. At the higher temperatures, commonly encountered in forging and heat treating, the activity of these two elements is greatly accelerated with the result that a compound very different from iron rust is formed. This compound is generally known as scale. The chemical composition of scale is variable and complex. It is sufficient for this discussion to bear in mind the significant fact that scale is a compound of iron and oxygen, formed in the temperature ranges of thermal treatment. This experimental work was conducted for the purpose of determining, first, the temperature at which scale begins to form, and secondly, the extent of scaling at common heat treating temperatures.

Procedure

A series of blocks were cut from low, medium and high carbon steels. Special attention was devoted to the cutting of the blocks in order that they should possess as nearly as possible the same dimensions and weight. The specimens were polished on a fine wheel, cyanided for 10 minutes at 1450 degrees Fahr., quenched in water and cleansed in a hot soda solution. This procedure served to remove the mill scale, rust or grease with which the surface of the bar stock may have been coated. The sample pieces were then carefully calipered and weighed.

The several grades of specimens were heated simultaneously in an electric muffle furnace for 1 hour each at different temperatures ranging from 900

A paper to be presented at the Detroit Convention October 2-7. The author. George C. McCormick, assistant metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

to 1700 degrees Fahr. The gases in the furnace at all times corresponded in analysis to the atmosphere of the room, which was:

Oxygen, 20 per cent
Carbon Dioxide, 0.2 per cent
Carbon Monoxide, nil
Nitrogen, 79.8 per cent by difference.

On removal from the furnace, the specimens were rapidly quenched in oil, the quantity of scale was then determined.

Method for Determining Scale

In determining the weight and thickness of the scale, it is mandatory to effect a complete removal of the oxidized layers without removing any metallic iron. Experiments were made with several chemical methods each of which were subject to the same criticisms—excessive removal of metallic iron or failure to completely remove the oxides.

A method was suggested of heating in cyanide for 10 minutes at 1450 degrees Fahr. followed by water quenching and cleansing in soda solution. This procedure was found to be conspicuously successful. The scale was

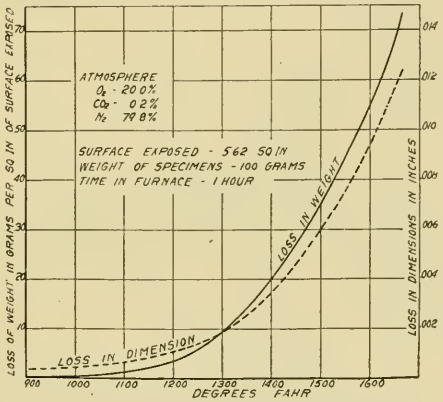

Fig. 1 Extent of scaling or oxidation on a 0.10-0.20 per cent carbon steel. It will be noted that the amount of scale formed below 1200 degrees Fahr. in 1 hour is practically negligible. Above this temperature the curve rises rapidly and at 1600 degrees Fahr. the specimen scaled on the average of 0.55 grams per square inch of surface exposed, and lost approximately .009 inch in each dimension.

completely removed by this unique application of cyaniding and specially prepared specimens cyanided in this manner, showed variations of dimension and weight so small as to have no effect upon the final results.

Fig. 1 is a graphical presentation of the extent of scaling on a 0.10-0.20 per cent carbon steel. Attention is called to the fact that below 1200 degrees Fahr. the amount of scale formed in 1 hour is practically negligible. Above this temperature, however, the curve rises rapidly and at 1600 degrees Fahr. the specimens scaled on the average 0.55 grams per square inch of surface exposed, and lost approximately 0.009 inch in each dimension.

Fig. 2 portrays the amount of scaling on a 0.50-0.60 per cent carbon steel. As in the case of the low carbon material, little scaling takes place below 1200 degrees Fahr. Attention is called to the extent of scaling at 1600 degrees Fahr. In this range, the metal scales 0.45 grams per square inch of surface exposed and loses 0.007 inches in each dimension.

In Fig. 3, the scaling of a 1.00 per cent carbon steel is depicted. As in the previous figures, little or no scale forms below 1200 degrees Fahr. In the higher temperature ranges, for example, at 1600 degrees Fahr., the steel loses 0.40 grams in weight for every square inch of surface exposed and suffers a decrease of 0.006 inches in each dimension.

Summary of Scale Formation

From a study of these curves, it is evident that,

1. Little or no scale forms below 1200 degrees Fahr.
2. The amount of scale formed under the given conditions varies inversely with the carbon content of the steel.
3. The formation of scale increases rapidly with the rise in temperature above 1200 degrees Fahr. and at 1600 degrees Fahr. may be fittingly described as excessive.

Kinds of Atmosphere

In furnace literature, frequent mention is made of "oxidizing," "neutral," and "reducing" atmospheres. Consideration has been given in this work to the extent of scale formation in an atmosphere containing 20 per cent oxygen. Such an atmosphere is described as "oxidizing" and permits of the

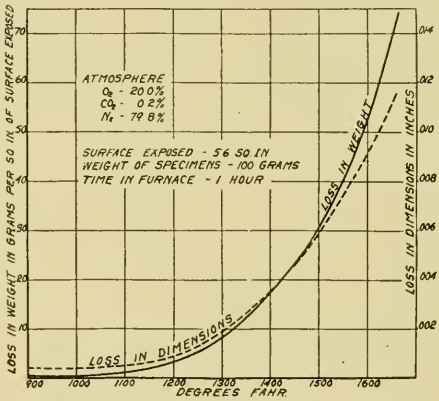

Fig. 2 Extent of scaling or oxidation on a 0.50—0.60 per cent carbon steel. As in the case of the low carbon steel very little oxidation takes place below 1200 degrees Fahr. It will be noted that the scaling at 1600 degrees Fahr. amounts to 0.45 grams per square inch of surface exposed and loses 0.007 inch in each dimension.

rapid formation of scale. Believing that certain misconceptions concerning the scaling properties of the "neutral" and "reducing" atmospheres are in existence, it is the writer's purpose to subsequently record the results of various experiments conducted in these atmospheres.

The Neutral Atmosphere

The distinctive qualities of the "neutral" atmosphere are as follows:

1. The absence of free oxygen.
2. The absence of combustible material.
3. The presence of either carbon dioxide or water vapor or both.
4. The presence of nitrogen.

It is logical, that a consideration of the effect of nitrogen, water vapor and carbon dioxide upon heated steel will throw light upon the non-scaling properties of the "neutral" atmosphere.

NITROGEN—Since scale is an oxide of iron, it is evident that nitrogen will not enter into the formation of scale and may be dismissed from the discussion.

WATER VAPOR—Chemistry has established beyond the shadow of doubt that when heated in the presence of iron, water vapor dissociates and reacts with iron to form scale. The reaction may be expressed as follows:

$$3\ Fe + 4\ H_2O = Fe_3O_4\ (Scale) + 4\ H_2$$

Thus, the second constituent of the so-called "neutral" atmosphere is capable of producing scale.

CARBON DIOXIDE—When heated in the presence of metallic iron breaks down and reacts with the metal to form scale as follows:

$$2\ Fe + 3\ CO_2 = Fe_2O_3\ (Scale) + 3\ CO$$

To establish the validity of this equation, experiments were conducted in which cylindrical pieces of steel were heated in a very slow current of pure

Table I
Scaling in Dry Carbon Dioxide
Specimens heated from room temperature to 1600-1700 degrees Fahr. and cooled slowly.

Experiment Number	Time at 1600-1700 Degrees Fahr.	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
1	2 hours	0.005	0.32
2	1 hour	0.003	0.19

Table II
Reducing Atmosphere
Extent of Scale Formation in Reducing Atmosphere—Analysis of Gases in Furnace Chamber:—Carbon Dioxide—15 per cent; Oxygen—0 per cent; Carbon Monoxide—0.4 per cent.
Temperature 1700 degrees Fahr. Time 1 hour

Material	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
Low Carbon Steel	0.014	0.70
Medium Carbon Steel	0.010	0.59
High Carbon Steel	0.008	0.57

dry carbon dioxide. The specimens were accurately weighed before the experiment and again after the scale which formed was removed by cyaniding. In the first experiment, the samples were placed in a slow stream of dry carbon dioxide at room temperature, heated rapidly to 1600-1700 degrees Fahr., held for 2 hours, and cooled slowly. The flow of carbon dioxide was maintained constant throughout the experiment. The second experiment was similar to the first with the exception that the time at 1600-1700 degrees Fahr. was 1 hour. Reference to Table I will indicate that the quantity of scale formed under the above conditions is quite appreciable. It is evident therefore, that carbon dioxide is capable of producing scale on heated steel.

The Presence of Carbon Monoxide

In considering the above experiments, it should be borne in mind that the gas introduced into the apparatus was pure dry carbon dioxide. Analysis of the gases issuing from the furnace revealed the presence of carbon monoxide. The percentage of carbon monoxide increased with the temperature from 2 per cent between 1100 and 1200 degrees Fahr. to 13 per cent

at 1600-1700 degrees Fahr. Regardless of the presence of carbon monoxide in the furnace, the fact remains that scale formed.

Summary of Neutral Atmosphere

The neutral atmosphere therefore contains two compounds, water vapor and carbon dioxide, which are active in the formation of scale. It is obviously an error to associate non-scaling properties with the neutral atmosphere.

The Reducing Atmosphere

The occurrence of a "reducing" atmosphere will be identified with the following conditions:

1. The presence of combustible material.
2. The absence of free oxygen.
3. The presence of either carbon dioxide or water vapor or both.
4. The presence of nitrogen.

For the purpose of determining the non-scaling properties of an artificial reducing atmosphere, experimental work was conducted in which pieces of steel were heated in mixtures consisting of dry carbon dioxide and illuminating gas. In the first experiment polished specimens were heated from room temperature to 1600-1700 degrees Fahr., held for 1 hour and allowed to cool slowly to room temperature. During the entire time of the experiment, the

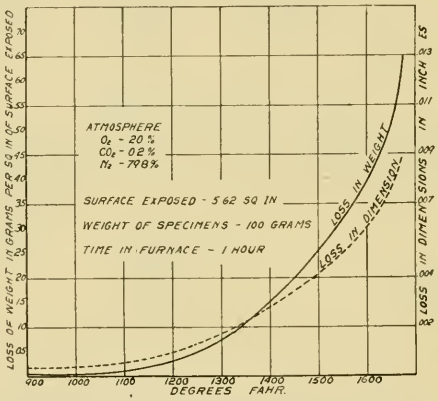

Fig. 3 Extent of scaling or oxidation on a 1.00 per cent carbon steel. Practically no scale forms below 1200 degrees Fahr. At 1600 degrees Fahr. the steel loses 0.40 grams in weight for each square inch of surface exposed and suffers a decrease in each dimension of 0.006 inches.

mixture of carbon dioxide and illuminating gas introduced into the apparatus was maintained constant at 63 per cent carbon dioxide and 37 per cent city gas by difference. No scaling was manifest on the pieces as they were removed from the furnace. The pieces retained traces of the original polish and were colored the dull bluish grey which is characteristic of carburized parts—an appearance with which all steel treaters are familiar. An additional experiment was conducted in which the percentage of illuminating gas was reduced to 10 per cent yielded very similar results. No scale was formed, and again the pieces had the appearance of having been carburized. These experiments on artificial reducing atmospheres renders apparent that it is possible to heat steel in mixtures of carbon dioxide and illuminating gas without the formation of scale. Such atmospheres may be correctly described

as non-scaling. However, the quantity of excess gas used in these experiments is prohibitive from the standpoint of both hygiene and economics.

Practical Reducing Atmospheres

In order to determine the scaling activity of reducing atmospheres in furnace operating under regular shop conditions, numerous experimental observations have been carried out. Test pieces of low, medium, and high carbon steel were held in a surface combustion furnace for 1 hour at 1700 degrees Fahr. The atmosphere in the furnace was slightly reducing and analyzed as follows:

Carbon dioxide, 15 per cent
Oxygen, 0 per cent
Carbon monoxide, 0.4 per cent

On removal from the furnace the pieces were rapidly quenched in water.

Table III
Reducing Atmosphere

Extent of Scale Formation in a Reducing Atmosphere—Analysis of Gases in Furnace Chamber:—Carbon Dioxide—11.5 per cent; Oxygen—0 per cent; Carbon Monoxide—0.8 per cent.

Temperature 1700 degrees Fahr. Time 1 hour

Material	Loss of Dimension in inches	Loss of Weight in Grams per square inch of Surface Exposed
Low Carbon Steel	0.007	0.41
Medium Carbon Steel	0.005	0.38
High Carbon Steel	0.004	0.35

Table IV
Comparison of Reducing and Oxidizing Atmospheres

	Scaling in Oxidizing Atmosphere 20 per cent Oxygen at 1675 degrees Fahr. Time 1 hour		Scaling in Reducing Atmosphere Carbon Dioxide—11.5 per cent; Oxygen—0 per cent; Carbon Monoxide—0.8 per cent. At 1700 degrees Fahr. Time 1 hour	
Material	Loss of Dimension in inches	Loss of Weight Grams per square inch of Surface Exposed	Loss of Dimension in inches	Loss of Weight Grams per square inch of Surface Exposed
Low Carbon Steel	0.013	0.75	0.007	0.41
Medium Carbon Steel	0.012	0.70	0.005	0.38
High Carbon Steel	0.009	0.65	0.004	0.35

The scale was determined by the cyaniding method previously described. Reference to Table II will show that the specimens scaled to an appreciable extent. Further work was conducted in an atmosphere containing a higher percentage of combustible gas. The analysis of this atmosphere yielded:

Carbon dioxide, 11.5 per cent
Oxygen, 0 per cent
Carbon monoxide, 0.8 per cent

Low, medium and high carbon specimens were used, and the general procedure was identical with the preceding experiment. The results are summarized in Table III.

By comparing Tables II and III, it will be noted that the quantity of

scale formed decreases with the increase in the percentage of reducing gas carbon dioxide present.

Comparison of Oxidizing and Reducing Atmospheres

Table IV has been prepared to show the comparative scaling activity of the oxidizing atmosphere cointaining 20 per cent oxygen and the reducing atmosphere.

Carbon dioxide, 11.5 per cent
Carbon monoxide, 0.8 per cent
Oxygen, 0 per cent

A survey of the Table IV will make evident that the scaling activity of the reducing atmosphere at 1700 degrees Fahr. is only half as intense as the scaling activity of the oxidizing atmosphere. Several experiments have been conducted in which small pieces of tool steel were held from 10 to 15 minutes at 1400-1600 degrees Fahr. in reducing atmospheres. The pieces were discolored but no measurable quantity of scale formed. It, therefore, appears logical to conclude that regardless of the presence of carbon dioxide in the furnace atmosphere, scaling will take place when the temperature is sufficiently high and the time of heating is sufficiently long.

Conclusions

As a result of the data obtained in the foregoing investigation the following conclusions are drawn.

1. In an atmosphere containing 20 per cent oxygen, little or no scale forms on steel exposed to a temperature of 1200 degrees Fahr. for 1 hour.
2. For straight carbon steels heated under identical conditions, the quantity of scale formed varies inversely with the carbon content of the metal.
3. The formation of scale becomes appreciable at 1200 degrees Fahr. in atmospheres containing 20 per cent oxygen, and from that point increases rapidly. At 1600 degrees Fahr., the quantity of scale formed may be fittingly described as excessive.
4. The neutral atmosphere, because of the carbon dioxide and water vapor which it contains, is active in the formation of scale.
5. Steel may be heated in mixtures of carbon dioxide and illuminating gas without the formation of scale. Such gaseous mixtures may be correctly described as non-scaling.
6. Reducing atmospheres, found under actual operating conditions, permit the formation of scale when the temperature is of sufficient intensity and when the time of heating is of adequate duration.
7. Pieces of steel may be heated for a short time in reducing atmospheres without the formation of appreciable quantities of scale.

THE TESTING OF METALS FOR HARDNESS

By S. P. Rockwell

THE term "hardness" is ambiguous and is rather indefinite in its meaning. We know that certain hardness tests show some materials to be hard, yet they can be filed or machined. High speed steel, for instance, by testing is found to be hard and yet soft to the file. Manganese steel can be sheared but cannot be machined. By the Brinell method of testing it is soft, but by the scleroscope method it is hard. Sealing wax by the scleroscope shows as hard as mild tool steel yet, when tested by the Brinell method, it flows and no reading can be taken. It evidently follows that the various hardness testers measure various properties of hardness. Hardness may be expressed by six ideas.

1. Cutting hardness, or the resistance of metals to various cutting operations. Keeps drill test was developed for use on castings to test this quality.

2. Abrasive hardness, or the resistance of metals to wear when subjected to rotative or sliding motion. In bearing metals this is measured by the sclerometer. Various special machines have been developed to test the wear caused by various load and lubrication conditions.

3. Tensile hardness, or the strength of metals in terms of elastic limit and ultimate strength, when such metals are ruptured, is determined in the ordinary universal testing machine.

4. Rebound hardness, or the elastic properties of the metal when allowed to strike and rebound. The scleroscope is the usual method of measuring these properties.

5. Indentation hardness, or the resistance metals offer to indentation. The Brinell method measures this property in terms of plasticity and the Rockwell in either terms of plasticity or density.

6. Deformation hardness, or the distortion properties of sheet metal. The Erichsen tester is used for this purpose by forcing the work through a die and measuring the distance it can be drawn before rupture.

This paper will deal with tests made on standard Brinell, Scleroscope and Rockwell hardness testing machines.

Adaptability of the Various Testers

The Rockwell Hardness Tester

The Rockwell hardness tester is at present made in three sizes, the Model 2A has an opening between chuck and testing point of 2¼ inches between the point of test and the frame 3 inches. The Model 2½A, 4½ and 5 inches. The Model 3A, 7 and 5 inches. All materials which can be accommodated in the respective openings can be tested. All models will test sheet steel on a comparison basis to 0.010 inches thick, brass on a comparison basis to 0.015 inches thick. Models 2A and 2½A will test steel wire on a comparison basis to 1/16 inch in diameter and brass wire on a comparison basis to 3/32 inches in diameter. Model 3A is not recommended for such small diameters, as low as ⅜ inches diameter wire or rod, however, it may be tested.

Absolute parallelism of test surface to test point is not necessary. The angle depends a good deal on the metal hardness and the danger of slippage

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A paper presented before the Indianapolis Convention. The author, S. P. Rockwell, is consulting metallurgist, Hartford, Conn.

or creep of the test specimen on the chuck. Polished surfaces are not necessary as light reflection is not a function of the hardness reading. Considerable surface scale does not materially affect readings as the minor pressure forces the testing point through this to the true metal beneath.

Hollow specimens may be tested with as great a degree of accuracy as solid objects. The limit is only controlled by whether the object is permanently deformed by the major pressure. Even in this case a special chuck or mandrel can be used to eliminate permanent shape deformation. Rollers, bushings and short tube lengths may be tested on either the outside or the inside. When tested on the inside a goose-neck chuck is used and the test point is placed in this. Axes can be tested within 1/8 inch or closer to the cutting edge on Model 2½A with a special form of fixture. Taps may be

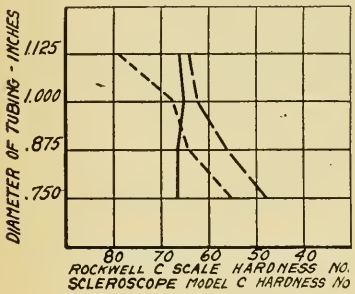

Fig. 1 Effect of the mass of the chuck in testing hardened, carburized steel tubing. Solid line—Rockwell test C scale. 120 degree diamond 150 kilogram pressure. Dotted line—Model C scleroscope on a V chuck. Dash line—Model C scleroscope on standard flat chuck.

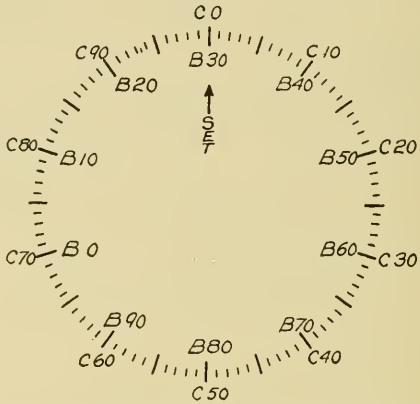

Fig. 2 Dial indicating hardness of metals when tested by the Rockwell tester. B—Scale is read when using 9/16 inch steel ball with a 100 kilogram load. C—Scale is read when using a 120 degree diamond cone with 150 kilogram pressure.

tested on the teeth by the use of centers and a quick moving support. In fact nearly everything requiring a test for hardness can be tested with the proper method of chucking.

The effect of mass of the chuck, providing it does not permanently deform or creep under the major pressure, has no effect on the hardness reading. See Fig. 1. The principle of the test allows for future possibilities in designing machines to test large gears, etc., that are in themselves too bulky to move. The weight of the testers vary from 55 pounds for Model 2A to 70 pounds for Model 3A. This weight makes it possible to grasp it by one hand and carry it about as desired. There is no need for leveling the instrument up, it operates correctly when set on the ordinary bench or table.

The speed of the operation depends on the operator, and the requirements of the test. If hardness comparison is to be made with tests conducted at another plant, 10 to 12 accurate tests may be made a minute. If inspection only is required, such as sorting, comparing, etc., 25 to 30 tests may be made a minute. The depth of impression is so slight that there are few objects found that cannot stand the small indentation made. The impression made in a ball race would not be wise. Due, however, to the accurate control of the point of test, a race can be tested just out of line of the ball travel.

The Rockwell tester beside being furnished with a considerable range of chuck, shapes, standard test blocks, etc., is equipped with 3 different weights

which apply loads of 60, 100 and 150 kilograms as they are desired for the different test points. The Brinell range is about 160 to 170 and up, and the scleroscope range is from 12 up. The readings are taken on the black figures of the C scale on the dial indicating the hardness. See Fig. 2. The load to be used with the diamond cone is the 150 kilograms load. A Rockwell reading then prefixed with the letter C is a standard reading and indicates the use of the diamond cone as the testing point and 150 kilograms as the major load. The minor load is 10 kilograms under all conditions of tests and the time 5 seconds. The 1/16 inch ball is for use on nearly all metals which have a range of good machinability to extra soft. The Brinell range is 50 to 220, and the scleroscope range up to 55. The readings are taken on the red figures of the B scale on the dial. The load to be used with the 1/16 inch ball is 100 kilograms load.

The Rockwell hardness number on the C scale (which scale applies when the diamond cone of 120 degrees angle and the 150 kilogram major load are used) is based on the depth to which the 150 kilogram major load drives the point below the depth to which it was initially driven by a 10 kilogram minor load. A direct measurement of the depth of impression would give a higher number for softer material, and so to conform to the accepted custom of a higher hardness number for harder materials, the depth indicator has the numbering in retrogression for progressive depth so that a reading of 20 means a deeper hole than a reading of 60 and the dial (on which each sub-division is equivalent to 0.002 millimeters motion of the test point) automatically subtracts the depth reading from 100 and therefore, the complement of the depth reading is the directly indicated hardness number. In a similar manner, the Rockwell hardness number on the B scale, which scale applies when the 1/16 inch steel ball and the 100 kilogram major load are used, is based on the depth to which the 100 kilogram major load drives the ball below the depth to which it was initially driven by a 10 kilogram minor load. If, however, the same scale on the dial was used, as is used for the diamond cone and the 150 kilogram load, there would be occasions when testing soft metals that the pointer would register less than zero. To avoid the confusion that might arise from having a minus or negative reading, the starting point has been moved 30 subdivisions. This means instead of starting the test at zero, it is started at 30. The steel ball would not hold its shape in tests on very hard steel and is not used for such tests and this together with the desire to spread the working range of the steel ball over a full revolution of the dial pointer has made it advisable to eliminate from the steel ball or B scale, readings that apply to shallow depth. This permits bringing into the range of the dial, the measurement of particularly deep impressions on very soft material without having such readings fall below zero hard. This is the reason that B-zero and B-100 are not at the top of the scale as C-zero and C-100 are, but are down in the southwest corner. If this were not done, readings from B-30 to B-zero could not be conveniently recorded inasmuch as they would be negative readings and lead to confusion. The numbering is retrogressive, as previously explained, for the C scale, only in this case, the depth reading is automatically subtracted from 130.

A Rockwell reading then prefixed with the letter B is a standard reading and indicates the use of the 1/16 inch ball as the testing point and 100 kilograms pressure as the major load. The life as regards permanent deformation of the 1/16 inch ball is increased if metals no harder than B-100 on the Rockwell scale are tested. By discarding such balls as have been used on

harder metals a greater degree of accuracy can be maintained. The 1/16 inch ball is a standard article and is made to size by a number of ball manufacturers. There are other materials which can be tested satisfactorily with any of the test points and with any of the loads. These materials might be die castings, fibre, etc. Any combinations of the points and loads not mentioned above would then be special cases and as such the test condition should always be stated so that comparison may be made. For instance, a test with a ⅛ inch ball with 60 kilograms major load read on the B scale would be recorded thus—⅛-60 B56, etc.

A further application of the Rockwell hardness tester with steel balls as testing points is in using the same as the Brinell machine, that is making the impression and measuring the diameter of the impression as a hardness number and computing to Brinell numbers. The impression diameter is easily read by using the ordinary Brinell microscope in place of the regular eyepiece of any ordinary microscope fitted with a 32 millimeter objective. This method is not recommended as it is not necessary. It, however, can be used where one wishes to use various hardness determinations, etc. This method is similar to the Baby Brinell method and the same microscope may be used.

The diamond has the ability to resist pressure with a minimum of wear. Diamond tipped tools have demonstrated this. Care should be used that no sudden blow is given them, as a fracture may be started.

The Shore Scleroscope Tests

The scleroscope is now regularly made in three models, C, C1 and D Model C is in most general use, then D. Model C1 has recently been placed on the market. The writer has as yet not used this instrument.

The scleroscope as furnished is equipped with a diamond tipped hammer, a set of test blocks to check the proper operation as regards the setup and diamond condition, a standard frame and chuck to hold the scleroscope proper and to test small objects not over 2 inches thick. The scleroscope proper may also be removed from its frame and attached to a swing arm so that very large objects are readily tested. A leveling device is attached so that the instrument may be set vertical.

The scleroscope decreases in its efficiency in detecting hardness changes as the hardness of the test work decreases. To rectify this condition a steel hammer can be procured called a magnifying hammer. This is to be used on soft work. This throws the hardness units into a different scale. Due to the repeated blows this hammer receives, it in itself changes hardness and must be replaced occasionally or else the results are misleading. The scleroscope test is affected in its readings by—

1. Mass and shape of piece being tested. See Fig. 1.
2. Mass of chuck under specimen. See Fig. 1
3. Hardness of chuck under specimen.
4. Smoothness and cleanliness of surface of test piece.

The Model D is apparently affected more by these conditions than is the Model C. In using the scleroscope the conditions of test should always be noted by the model used, the method of chucking, a sketch of the piece tested, and where, noted on it. If this were always done there would be less confusion in interpreting results.

The Bureau of Standards report, "In working with the scleroscope it was found that the hammer must be calibrated after a certain number of tests. For this purpose a piece of steel hardened to 100 scleroscope must be used. The rebound for any given steel cannot be corrected by proportionate decrease or increase if the hammer gives a rebound either less or greater

than 100 on the hardened steel. This shows that a slight change in the form of the hammer assigns the metal tested to a different position in the hardness scale."

It is the diamond in the hammer that is eventually damaged by the sudden shocks it receives. The prolongation of the diamond's life can be secured by never testing twice on the same spot and this will prevent the diamond striking super-hard metal.

The Brinell Test

There are a great many types of Brinell testers. They are, as a rule, supplied with a series of weights to give loads from 500 kilograms up to 6000 kilograms. The dead weight testers, however, can be used for any intermediate load. Any size ball and under nearly any load condition can be used. The standard for Brinell test is the 10±.0025 millimeters steel ball with 3000 kilograms load for hard metals and 500 kilogram load for soft metals, the time 30 seconds. Due to a variance in deformation of balls under different loads, the different test conditions assign the piece tested to a different hardness scale. It is always best in giving Brinell hardness to note the conditions of test.

A microscope and a marked scale for calibrating is, as a rule, furnished with the tester to measure the diameter of the impression which is the unit of hardness. Many plants are using this unit to specify their hardness as it saves time in computing or comparing with a chart to determine the Brinell number, which increases rapidly with each unit increase in actual hardness. The errors are due to poor light reflection to the microscope, and to ball flattening. Where very accurate results are desired, a new ball is used for every test and the diameter of the impression is read twice at right angles and the average taken as the hardness unit. Commercially this is seldom done. Usually due to the time consumed in making a test only one impression is made. As it is the exception to find a piece of metal of uniform hardness it is often wise to take several readings if conditions warrant. As the reading of hardness depends on the reflection of the indentation back to the eye through the microscope, a bright surface must be made on the metal tested and this is usually done by polishing lightly with emery. On rounded articles a flat surface is prepared by grinding. If the test surface is flat the indentation will be circular and error in this case is lessened.

A number of makers of standard Brinell machines have developed depth reading devices. These have not been generally accepted for two reasons; first, no reliable conversions were worked out between depth and diameter of indentation, and second, because the average Brinell tester is not delicate enough in its load application to apply a constant minor pressure before and after test.

The greatest thickness of metal which can be tested by the Brinell testers depends only on the design of the tester itself. As regards thin sections, roughly accurate results cannot be secured on specimens which are less than 16 times the impression depth. Much thinner pieces may be tested for comparative results, in which case the metal tested is assigned to a different position on the hardness scale. Parts which cannot stand the load applied without permanent deformation, can often be tested only at the loss of the part. High speed steel tools should never be tested with the Brinell as hardened high speed always cracks radially from the indentation.

Description of Operation of Testing Machines

The Rockwell Test

The Rockwell test consists of impressing a hard object (harder than the

metal tested) into the metal, and noting the depth of indentation. The test points and weights used are of small size so that no more damage is done to the work than is absolutely necessary in order to make the test. The small size test point also makes it possible to test on very small areas. As the curvature of the point is small, concave and convex surfaces of very small radius may be tested accurately. As the measurements of depth are very small, they are magnified through a 5 to 1 lever to a 100 to 1 indicating dial. This means that each unit on the dial is 0.002 millimeters, or approximately 0.00008 inch. This again means that the actual depth of penetration or marring on the softest steel is only about 0.2 millimeters, or .008 inch.

Where such close measurements are used, it is necessary to have a definite minor pressure of application of test point against work, which is to remain constant at the beginning and end of depth measurement. This is analogous to the ratchet stop with the micrometer. This is done by a calibrated spring in the head of the machine. This spring is under compression at all times. Its total action under test is confined to about 1/16 inch action during which time its difference of exerted pressure is negligible.

The work to be tested is placed on the chuck and a clockwise rotation of the hand wheel raises the work in contact with the testing point. At this moment the minor pressure begins to apply. The handwheel motion is continued until the ferrule on the dial approaches the line on the stem. The pointer now stands somewhere in a vertical position, or if not, the handwheel can be turned further to cause the pointer to be nearly vertical. The dial is then turned (if necessary) in order to bring the C-zero, or arrow on the dial to coincide with the pointer. The minor pressure is then fully applied.

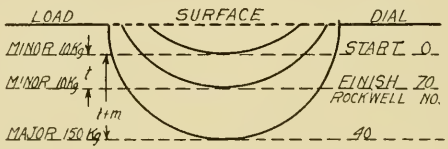

Fig. 3 Diagrammatic sketch of the process of identing while testing a specimen with the Rockwell tester.

Reference to Fig. 3 will show this and the following functions of the test. The minor pressure causes a slight penetration of the test point into the steel which point is used for an index mark zero.

By touching a small button at the right of the machine, a clockwork mechanism is set in motion which slowly lowers a weight on the left of the machine. This weight is called the major pressure and its actual weight is increased through a series of levers so that it is multiplied many times on the testing point itself. This load has now forced the test point further into the metal as shown in Fig. 3, and shows as t+m. This t+m is the penetration of the testing point in the work, the deflection of the work and the deflection of the testing machine. The hand lever at the right of the tester is now brought back or cocked. This winds up the clock mechanism and leaves the tester ready for another test. By bringing back this hand lever the major pressure is removed, leaving the minor pressure applied as at the beginning. This releases the deflection of the tester, the deflection of the work and leaves the testing point imbedded in the material to the exact depth of indentation Fig. 3, this depth t is shown in Rockwell hardness units on the dial. The hand-wheel is now turned counter clockwise and the test piece moved or changed for another test.

In order to control the rate of application of the major load the clock-

work mechanism is controlled by a leather clutch, the tension of which is controlled by a knurled screw inside at point of machine. The clutch should be adjusted so that the hand lever describes its arc in 5 seconds, commercially from 3 to 10 seconds may be used. The speed may be increased when very fast testing is desired. Doing this, however, causes the major pressure to exert a blow which transfers hardness to a different scale. Where the tester is used merely in sorting work this speeding up is permissable.

The Brinell Method

The Brinell tests comprise the impressing of a steel ball under a known pressure in the metal to be tested. As the diameter of the impression is the basis of the Brinell hardness unit, the test piece must be flat so as to make a circular impression and bright enough to be read by the microscope.

There are a number of different mechanical principles used in making the Brinell test. The dead weight principle where the work is forced up against the testing point until a scale beam is balanced at the desired load. The standard tensile testing machine is used in this manner. The hydraulic machine is usually used as its construction is lighter and faster in load application.

In this case the test work is placed on a chuck and a handwheel raises the work against a steel ball as a testing point. A valve in the head of the machine is then closed and a pressure is exerted on the ball through a piston by an oil hydraulic pump. A pressure gauge shows the pressure increase and as the pressure approaches that desired, the pumping should be slowed up. When the desired pressure has been obtained a balanced T lever, previously weighted, raises and after a certain height, automatically releases the pressure. This is a safety device to insure that the pressure may not be exceeded. Proper manipulation, however, requires one to raise these weights by hand just before the pressure has been secured with the hand pump, and carefully lowering them after the pressure has been obtained. This prevents an excess of weight which would cause a faulty hardness reading. This pressure is maintained from 15 seconds for hard metals to 30 seconds for soft metals. This time element is necessary on account of the plasticity of metals, and an equilibrium between the pressure of the steel ball and the steel must be obtained.

The valve in the head of the machine is now opened, which releases the pressure. The chuck containing the metal under test is then lowered and the test piece removed. The test piece is then taken to a strong light and the diameter of the impression made by the steel ball and the pressure is read twice 90 degrees apart by the aid of a microscope containing a scale. The diameters are read in millimeters, are averaged and, by the use of a chart, are converted into Brinell numbers.

The unit of Brinell hardness is .05 millimeter. The Brinell number is not a unit. On hardened tool steel, one unit is about 30 Brinell numbers and on annealed tool steel is about 4 Brinell numbers.

The Scleroscope Test

The scleroscope hardness test is made by dropping a diamond tipped hammer on to the metal to be tested and noting the rebound of the hammer. There are, in general use, two types of machines, the Model C being the older type is perhaps in most general use. A glass tube holds the hammer and serves as a guide for it. The hammer is raised to the top of the tube by air suction and maintained there by a mechanical catch. It is released by an air valve which trips this mechanical catch. A hand bulb furnishes the air to actuate the various functions in rotative order.

To operate, the instrument is carefully leveled by an attached leveling

device. This prevents friction between the hammer and the glass tube. The work to be tested is then placed on the chuck and the glass tube and its housing is lowered by rack and pinion until contact is made. By means of the air bulb the hammer is released which falls striking the test block and rebounds. The height of rebound is noted on a scale divided into 120 arbitrary equal parts at the back of the glass tube. The glass tube is now raised, and test piece moved and another test made. Extreme high or low readings are ignored and the rest averaged. The glass tube and its housing can be removed to a swing fixture so that an object too large to test on the regular chuck can be held in a vise and tested. The Model D instrument, brought out just previous to the World War, is mechanically different. The diamond tipped hammer is much heavier and in order to apply the same impact falls from a proportionately shorter distance. Its release is effected by a mechanical 3 ball clutch actuated by a knurled button. The same 3 ball clutch holds the hammer at the maximum rebound, the return of the knurled button causes their height to be measured and shown on a dial divided into arbitrary equal parts. This model may be used on a swing arm for large objects the same as Model C. The hardness units are the same. Due, however, to unexplained differences in physical impact, certain conditions of test piece shape and chucking will give different readings.

The need of leveling the instrument and the averaging of the test results is the same as for the Model C instrument.

Tests Conducted

Seven bars, one each of the following steels were selected for test:

1. Vulcan Vanadium
2. Ketos
3. Rex A A
4. S.A.E. 2330
5. Carpenter Monitor Tool Steel
6. Carpenter Tool Steel
7. Jessop Tool Steel.

These bars were first annealed, then 1/16 inch of the surface was removed by machining and ten-thousandths by grinding to make smooth and parallel surfaces. Each bar was then cut into 13 pieces, and all hardened at the proper temperatures and in the proper quenching mediums. After hardening, 12 of the pieces were each drawn back in a Hump furnace, for thirty minutes at temperatures 320, 400, 500, respectively through 1400 degrees Fahr. Before testing, each piece was ground ten-thousandths on a side in 3 cuts of the emery wheel. To remove any surface softening which might be caused by the grinding, each piece was carefully lapped on fine emery cloth. Each piece was of sufficient thickness and mass to insure uniform testing conditions for each method of test.

The pieces were first tested on a Model C scleroscope, which was first leveled and tested satisfactorily with the 100 test block furnished. Twenty readings were recorded, the ten best readings being selected for the hardness determinations, which are recorded on Figs. 4, 5, 6, 7, 8, 9 and 10. The pieces were then tested on the Model D scleroscope, which likewise was leveled and checked. The same method was used in recording readings.

The pieces were then tested on three different Rockwell hardness testers with two diamond cone testing points. Five readings were taken under each condition and each reading used in the hardness determination as shown in

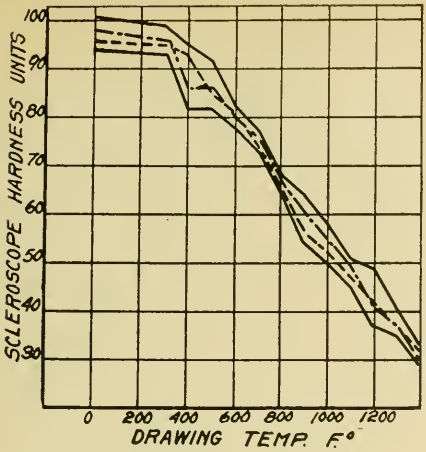

Fig. 4 Vulcan Vanadium Tool Steel. Size of specimens, 1¼ x 1¼ x ¾ inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

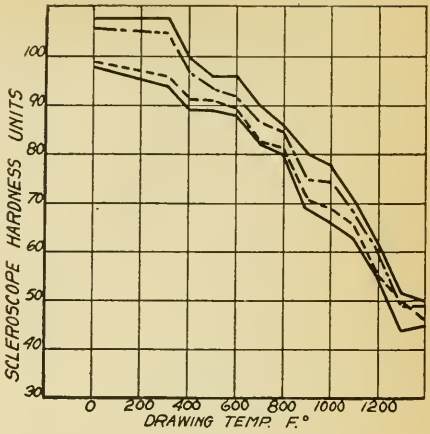

Fig. 5 Ketos Oil Hardening Steel. Size of specimens 1¼ x 1¼ x ¾ inches. Machined, ground, hardened in oil 1430 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

Figs. 11, 12, 13, 14, 15, 16 and 17. Two of the Rockwell testers were new and one had been in use at least two months.

The pieces were then tested on an Olsen hydraulic Brinell machine. This

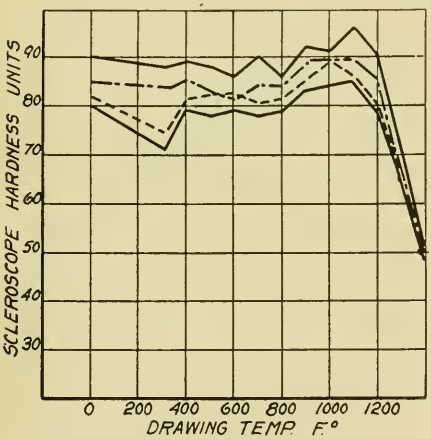

Fig. 6 Rex AA High Speed Steel. Size of specimens, 1¼ x 1 x $\frac{5}{16}$ inches. Machined, ground, hardened in oil 2300 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

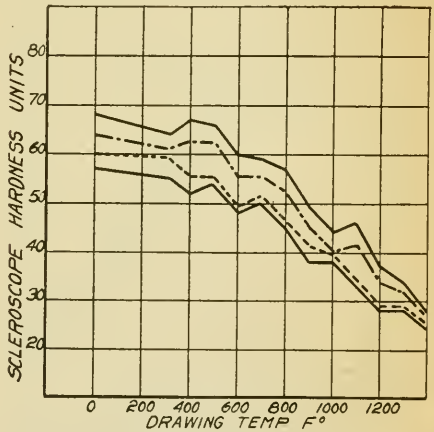

Fig. 7 S.A.E 2330 Steel. Size of specimens, 1¼ x ¾ x $\frac{7}{16}$ inches. Machined, ground, hardened in brine 1550 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

Brinell machine is in daily use and checked satisfactorily with various other concerns. Two readings were taken, the time on all specimens was 15 seconds. The diameter was read twice at 90 degrees apart and the average used for hardness determinations as shown in Figs. 18, 19, 20, 21, 22, 23 and 24.

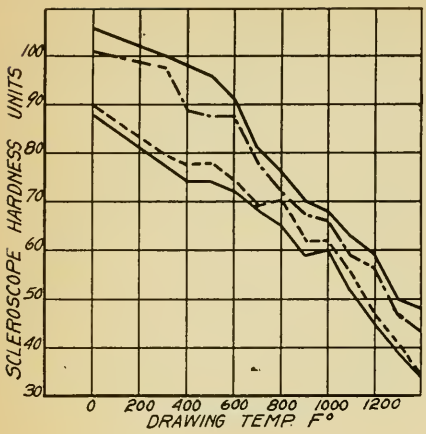

Fig. 8 Carpenter Monitor Tool Steel. Size of specimens, 1¼ x ¾ x ½ inches. Machined, ground, hardened in water 1500 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

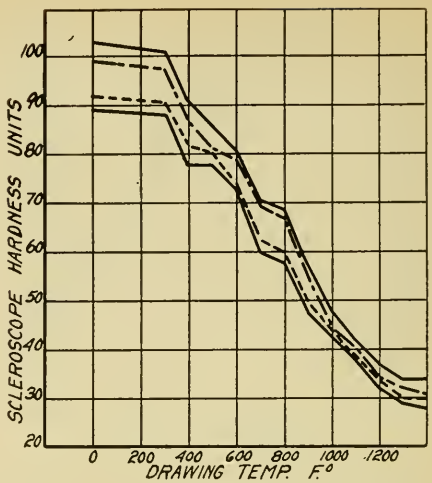

Fig. 9 Carpenter Tool Steel. Size of specimens. 1⅛ x 1 x 1/16 inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

The tests were then duplicated on a Riehle dead-weight Brinell machine, which checked with other machines. The same method was used to determine the hardness as with the previous test.

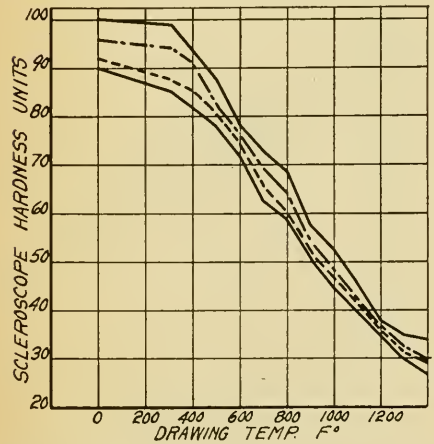

Fig. 10 Jessop Tool Steel. Size of specimens, 1¼ x 1⅛ x ½ inches. Machined, ground, hardened in water 1450 degrees Fahr., ground and polished. Thirteen pieces each drawn in electric furnace for 30 minutes. Solid line shows variation of 10 best of 20 scleroscope readings on model C and D scleroscopes. Dotted line average of 10 model C scleroscope readings. Dot-dash line average of 10 model D scleroscope readings.

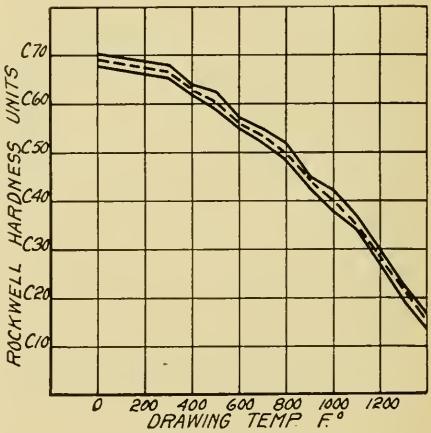

Fig. 11 Vulcan Vanadium Tool Steel. Size of specimens, 1¼ x 1¼ x ¾ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

On the Brinell test one ball only was used for all samples tested on one type of machine. The samples drawn at 1400 degrees Fahr., were first tested, then 1300 degrees Fahr., etc. This method approximates the usual

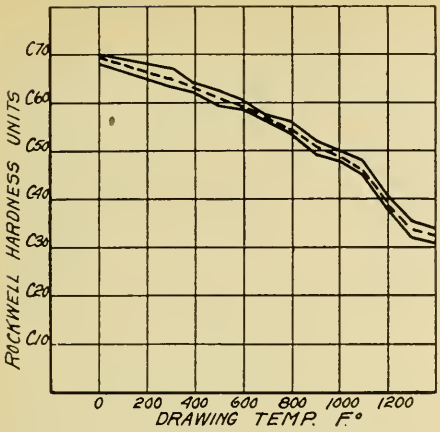

Fig. 12 Ketos Oil Hardening Steel. Size of specimens, 1¼ x ⅞ x ½ inches. Machined, ground, hardened 1430 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

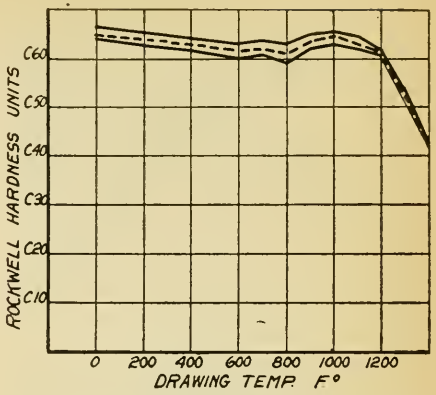

Fig. 13 Rex AA High Speed Steel. Size of specimens 1¼ x 1 x 3/16 inches. Machined, ground, hardened 2300 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

commercial factory conditions of test. The harder specimens were first rubbed over lightly with Prussian blue, so as to assist in reading the diameter of the impression. The microscopes were carefully checked before tests on the

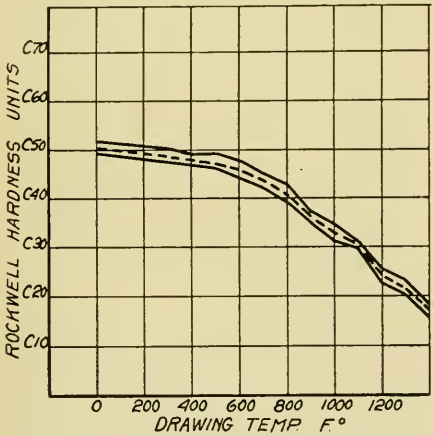

Fig. 14 S.A.E. 2330 Steel. Size of specimens, 1¼ x ¾ x 7/16 inches. Machined, ground, hardened 1550 degrees Fahr., quenched in brine, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

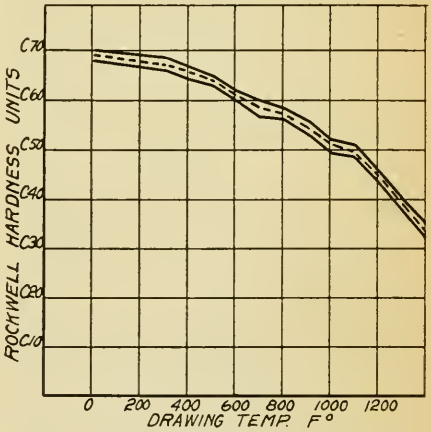

Fig. 15 Carpenter Monitor Tool Steel. Size of specimens, 1¼ x ¾ x ½ inches. Machined, ground, hardened 1500 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test conditions.

standard scale and with each other. The impressions were made half way between center and edge of specimen. In all other tests with the scleroscope and Rockwell tester, the specimens were tested at various parts of the surface so that average conditions were obtained. All tests by scleroscope, Rock-

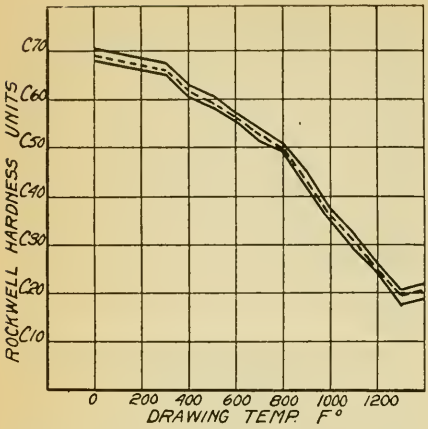

Fig. 16 Carpenter Tool Steel. Size of specimens, $1\frac{1}{8}$ x 1 x $\frac{1}{16}$ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average value of above test conditions.

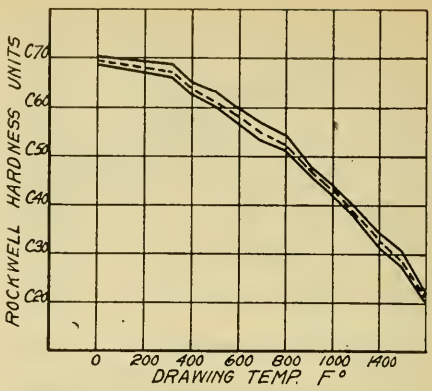

Fig. 17 Jessop Tool Steel. Size of specimens, $1\frac{1}{4}$ x $1\frac{1}{8}$ x $\frac{1}{2}$ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces, each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation of readings of hardness taken on 3 Rockwell hardness testing machines and 2 diamond points. 5 readings under each condition. Dotted line shows average values of above test condition.

well and Brinell were conducted on one side of the specimen, so that good chuck surface would be assured for all tests.

Conversion in General

In converting values determined by one form of hardness measurement to another, we must bear in mind that the conditions of a test enter into the

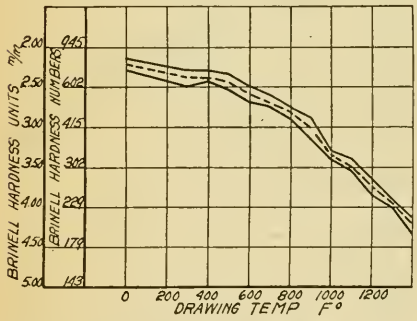

Fig. 18 Vulcan Vanadium Tool Steel. Size of specimens, $1\frac{1}{4}$ x $1\frac{1}{4}$ x $\frac{3}{4}$ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation on Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

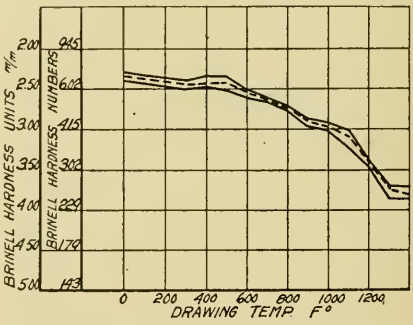

Fig. 19 Ketos Oil Hardening Steel. Size of specimens, $1\frac{1}{4}$ x $\frac{7}{8}$ x $\frac{1}{2}$ inches. Machined, ground, hardened 1430 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

matter. The same area tested by one means can not be used for test by another means, because at the completion of the test the metal is not in the same physical forms as before. Secondly, each different method of test affects a different area of metal and at a different depth. For this reason, no one method of test can be reliably complete. Furthermore, metals compared must be as homogeneous throughout as pos-

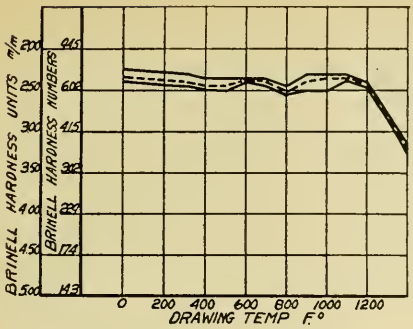

Fig. 20 Rex AA High Speed Steel. Size of specimens, 1¼ x 1 x $\frac{3}{16}$ inches. Machined, ground, hardened 2300 degrees Fahr., quenched in oil, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

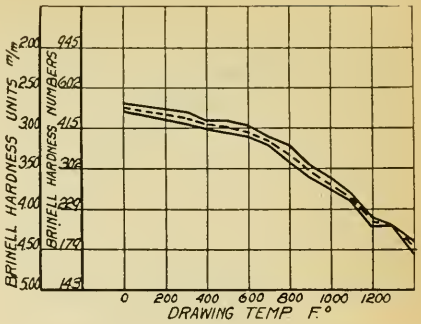

Fig. 21 S.A.E. 2330 Steel. Carbon .30 per cent Nickel 3.5 per cent. Size of specimens, 1¼ x ¾ x $\frac{7}{16}$ inches. Machined, ground, hardened 1550 degrees Fahr., quenched in brine, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

sible. For instance, a light depth, say 1/32 inch, of carburized steel cannot be tested accurately as regards the case-hardness by the Brinell. In the case of the scleroscope, the hardness is affected by the hardness of the core. As regards the Rockwell test, if the case is not actually punched into the core, a true hardness reading is given. This reading for comparison, however, to Brinell or scleroscope, necessitates that the comparison be made to Brinell and

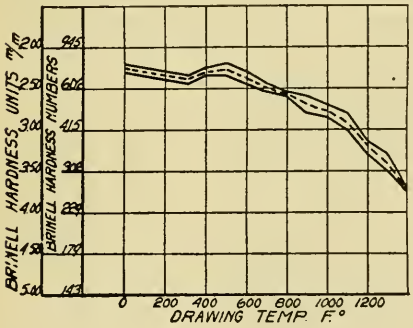

Fig. 22 Carpenter Monitor Tool Steel. Size of specimens, 1¼ x ¾ x ½ inches. Machined, ground, hardened 1500 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

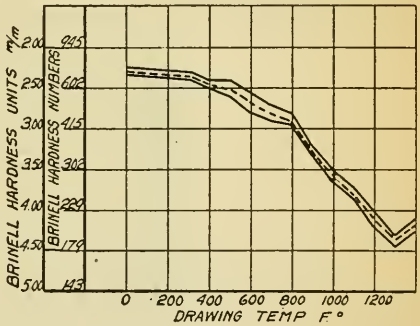

Fig. 23 Carpenter Tool Steel. Size of specimens, 1½ x 1 x $\frac{7}{16}$ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

scleroscope tests made on homogeneous steel and of volume enough so that metal thickness does not enter into the problem.

Brinell Test

The formula for Brinell hardness number is $BHN = \frac{P}{\pi Dt}$ where P is pressure applied, D is the diameter of the ball used in making the impression, and t is the depth of the impression.

The depth t in Brinell practice has not been used due mainly to me-

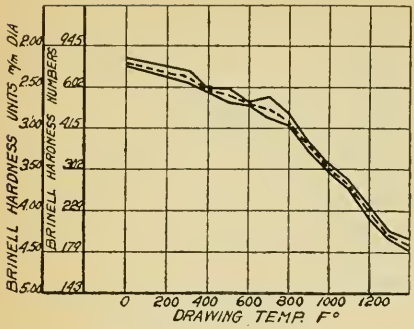

Fig. 24 Jessop Tool Steel. Size of specimens, 1¼ x 1⅛ x ½ inches. Machined, ground, hardened 1450 degrees Fahr., quenched in water, ground, polished, tested. Thirteen pieces each drawn in an electric furnace for 30 minutes at temperatures indicated. Solid lines show variation in Brinell hardness units taken on an Olsen hydraulic Brinell tester and a Riehle dead weight Brinell tester. Dotted line shows average of above conditions.

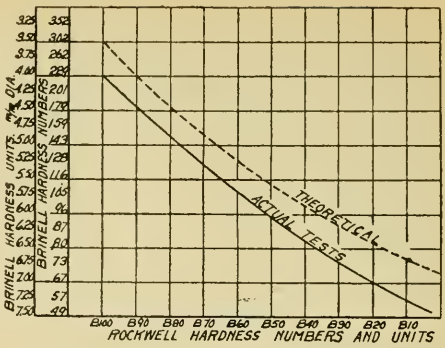

Fig. 25 Conversion chart showing theoretical and actual test data for testing common brass. Rockwell test used a $\frac{1}{16}$ inch steel ball with a 100 kilogram load. Brinell test used a 10 millimeter ball 3000 and 500 kilogram loads.

chanical difficulties in measurement. By the use of the spherical segment equation the depth t is calculated by formula $t = \frac{D}{2}\sqrt{\frac{D^2}{4} - \frac{d^2}{4}}$ where D is the diameter of the ball used in making the impression and d is the diameter of the impression thus made.

The conventional Brinell table is then made up on the assumption that the Brinell impression is a true spherical segment of the ball making the test.

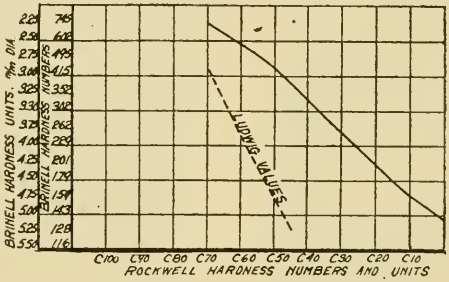

Fig. 26 Conversion chart showing the Ludwig Rockwell and Brinell number relationship. Data taken from tests shown in Figs. 4-24. Rockwell test used 120-degree diamond cone with 150 kilogram load. Brinell test used 10 millimeter ball with a 3000 kilogram load.

This assumption is, however, not correct for two reasons. First, a deformation of the ball used in making the test. This deformation is greatest on the hardest metals due to least amount of support. Second, a recoverance of the metal under test, which is in proportion to the work applied, the work being greatest at the point of greatest depth and decreasing toward the rim of the impression.

An example to demonstrate this is here cited. A piece of 0.35 per cent carbon steel was Brinelled and the impression diameter was 4.00 millimeters. By the spherical segment formula the depth should be 0.42 millimeter. On actual and close measurement, the actual depth after the load had been released was 0.29 millimeter. This was then a loss of 0.13 millimeter in depth,

which was due in part to ball deformation and in part to recoverance of metal. If the Brinell number is calculated from actual depth 0.29 millimeter, the result is 329. The Brinell number calculated from the actual diameter 4.00 millimeters, is 228. It is also observed that various metals tested are subject to various degrees of recoverance. It is, therefore, logical to assume that various Brinell balls, due to a difference in composition and heat-treatment, may have different elastic deformations.

A realization of these conditions explains to a more or less extent the following: the reason that two metals of the same Brinell hardness have different machining qualities, and the reason the various depth reading attachments furnished for Brinell machines have failed to check Brinell read-

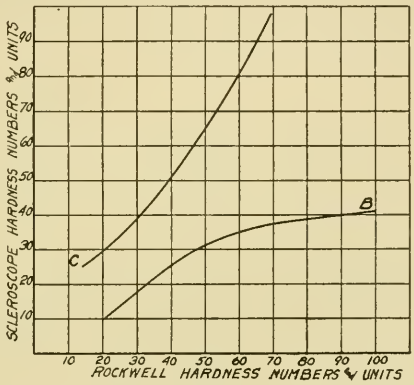

Fig. 27 Experimental test conversion chart of Rockwell test to scleroscope hardness numbers. Curve B, shows results obtained in testing common brass. Rockwell test used $\frac{1}{16}$ inch steel ball with 100 kilogram load. Scleroscope model C. Curve C, shows results obtained from data in test shown in Figs. 4-24. Rockwell test used 120 degree diamond cone with 150 kilogram load. Model C and D averages from scleroscope tests.

ings obtained by diameter calculation and that the calculation of hardness by depth measurement brings in other properties of metal than Brinell by diameter which is usually accepted as a degree of the plasticity of the metal.

Bearing these conditions in mind, we see that with a depth reading hardness tester working on the impression principle we can compare depths in terms of Brinell hardness numbers by a theoretical conversion scale or by the existing conventional conversion scale. The theoretical conversion is merely a question of mathematics. The conventional conversion, on the other hand, cannot be applied mathematically as the conventional scale does not allow for a multitude of varieties of balls and materials. Therefore, the conventional conversion must be made by experimental test results.

Scleroscope Test

As the scleroscope hardness depends on the height of rebound of the hammer, and as the indentation made by the hammer on the steel is too small to measure by depth, and as the bounding edge of the identation is not circular, mathematics can not be used to draw a relation between height of rebound and indentation measurements.

Therefore, in converting scleroscope hardness units to hardness units of any other system a theoretical conversion is not available, and any conversion must be made by experimental test results. It is found that metals of differ-

ent composition have an effect on the conversions, so that no one conversion chart can exactly apply to all metals. As the commercial methods of testing are conducted, however, a general conversion is commercially practical.

Conversion of Rockwell Hardness Units to Brinell Numbers

There are two standard conditions of Rockwell tests:

1. The standard 1/16-inch diameter steel ball under 100 kilogram load.
2. The standard 120-degree diamond cone under 150 kilogram load.

There are many other combinations of ball sizes and loads which convertible both by theory and test need not be considered in this paper as they are special conditions and where used should be stated.

Conversion for Rockwell with 1/16 inch Steel Ball 100 Kilogram Load

The Brinnell hardness number formula is

1, $BHN = \frac{P}{\pi Dt}$, where P = Pressure in kilograms.
D = Diameter of ball used in making impression.
t = Depth of impression thus made.

On the Rockwell tester two pressures are used causing two different depth impressions:

t 1 due to minor load P = 10 kilograms.
t 2 due to increment of total load P = P2 = 90 kilograms.
t 1 + t 2 = t; major or total load P = 100 kilograms.
Further, D ball diameter = 1/16 inch = 1.58 milimeters.

Substituting in equation 1, we have:

2. $BHN = \frac{P1+P2}{\pi D(t1+t2)} = \frac{P}{\pi D(t1+t2)}$

Now, unlike the relation between pressure and diameter of impression, the ratio of the pressure to the depth of the impression is proportional or

$$\frac{P1}{P2} = \frac{t1}{t2} \text{ solving for } t1 = \frac{P1t2}{P2}$$

Substituting in equation 2.

3. $BHN = \frac{P}{\pi D\left(\frac{P1t2}{P2}+t2\right)} = \frac{P}{\pi Dt2\left(\frac{P1}{P2}+1\right)}$

Substituting the known values in equation 3, we have:

4. $BHN = \frac{18.2}{t2}$

Now the Rockwell unit is 0.002 millimeters; and the hardness number is the difference between the measurement of depth and an arbitrary figure of 130*.

$$t2 = (130—R) \qquad 0.002 = 0.26—.002\ R$$

Substituting in equation 4, we have:

5. $BHN = \frac{18.2}{(130—R).002} = \frac{9100}{130—R}$

*See preceding text as regards the Figure 130.

The dotted curve on Fig. 25 is the theoretical conversion Rockwell to Brinell by the above equation under the above conditions. This varies considerably from the solid line curve which is the experimental test conversion curve. The reason for this is the ball deformation and test metal recoverance mentioned before.

The solid line is for all commercial practice satisfied by the formula.

$$BHN = \frac{6870}{130-R}$$

Conversion of the 120 *Degree Diamond Point* 150 *Kilogram Load into Brinell*

The cone test proposed by Ludwig calculated the hardness numerals from the pressure divided by the area of the projected impression. The area of the impression was figured by the measurement of depth of indentation t.

$$LHN = \frac{P}{\pi r^2}$$

Where P was pressure in kilograms and
r = t+tang. of half of the cone angle.

The relation of load depth and impressions of a cone bear no relationship to that of a sphere, so that no theoretical conversion can exist.

On Fig. 26 the dotted curve shows the Ludwig Rockwell conversion, the Brinell number in this case may be used as Ludwig numbers. On the same chart the solid curve represents the experimental test conversion curve for the Rockwell numbers to the conventional Brinell system. The solid line for commercial use is satisfied by the formula.

$$\text{Brinell diameter in millimeters} = .0465\ (100-R)+.55$$

Experimental Test Conversion of Rockwell With 1/16 *inch Steel Ball* 100 *Kilogram Load to Scleroscope Hardness Numbers*

This work was done on nonferrous metals. The solid line B, Fig 27, shows the average of results obtained from these tests.

Experimental Test Conversion of Rockwell With 120 *Degree Diamond Cone and* 150 *Kilogram Load*

This work was done on the steels mentioned in the body of this paper. The solid line C, Fig. 27, shows the average of results obtained from these tests.

The curve C is commercially satisfied by the equation:

$$S = \frac{R^2}{60} + 23$$

Conversion Tables from Tests

Conversion Table I for the Rockwell C scale was derived as follows: The Rockwell, scleroscope and Brinell values were obtained from the tests shown by Figs. 4-24. The column headed "Ultimate pounds per square inch" is the conventional table as figured from the Brinell hardness number by the formula.

$$\text{Pounds per square inch} = BHN \times 494$$

The Rockwell tester may be used to commercially read in scleroscope numbers by using a different zero point on the C scale as a starting point for tests.

When Scleroscope Specifications call for	Start Tests on Rockwell Tester at (and read on C scale as Scleroscope Number)
95—105	C 30
90—100	C 26
85— 95	C 24
80— 90	C 22
75— 85	C 20
70— 80	C 18
65— 75	C 17
60— 70	C 15
55— 65	C 13
50— 60	C 11
45— 55	C 10
30— 50	C 9
25— 35	C 10
20— 30	C 11
15— 25	C 13

Conversion Table II for the Rockwell B scale was derived from tests 6, 4 and 2 number hard common brass, annealed in the same manner as the steel samples mentioned in this paper were drawn. The Rockwell, scleroscope and Brinell values are the average of these tests. The Brinell indentations were made at 500 kilograms pressure using a 10 millimeter ball. The column of millimeter diameters under 3000 kilograms is added to show the equivalent diameter at 3000 kilograms. The scleroscope values were obtained on the Model C scleroscope chucked on the standard frame chuck. The brass was in all cases 0.077 inch gauge, smooth and bright of surface.

CONVERSION TABLE I

Rockwell C scale 120 degree Cone 150 kilogram Load	Scleroscope Average of Models C & D Scleroscopes	Brinell millimeter diam. 10 millimeter ball 3000 kilogram Load	Brinell Numbers	Ultimate Strength pounds per square inch
75	..	.....	...	.....
74	..	.....	...	.....
73	..	.....	...	.....
72	..	.....	...	.....
71	..	.....	...	.....
70	98	2.25	745	366,600
69	96	2.255	725	357,000
68	94	2.30	712	350,600
67	92	2.35	682	335,700
66	90	2.375	668	327,000
65	88	2.40	654	323,000
64	87	2.45	627	3008,40
63	85	2.475	614	390,000
62	83	2.50	602	26,5000
61	82	2.525	590	290,000
60	80	2.55	578	284,300
59	78	2.60	555	273,300
58	77	2.625	545	268,000
57	75	2.65	534	263,000
56	74	2.70	514	254,000
55	72	2.725	504	248,600
54	71	2.75	495	243,800
53	69	2.80	478	235,100

(Continued)

CONVERSION TABLE I (Continued)

Rockwell C scale 120 degree Cone 150 kilogram Load	Scleroscope Average of Models C & D Scleroscopes	Brinell millimeter diam. 10 millimeter ball 3000 kilogram Load	Brinell Numbers	Ultimate Strength pounds per square inch
52	67	2.85	461	226,400
51	66	2.872	452	222,300
50	65	2.90	444	218,700
49	64	2.95	429	211,100
48	63	3.00	415	203,800
47	61	3.05	401	197,200
46	59	3.10	388	190,900
45	57	3.15	375	184,600
44	56	3.20	363	178,700
43	54	3.25	352	173,300
42	53	3.275	346	170,100
41	52	3.30	341	167,900
40	50	3.35	331	162,600
39	49	3.40	321	157,800
38	48	3.45	311	153,100
37	47	3.50	302	148,600
36	45	3.55	293	144,300
35	44	3.60	285	140,100
34	43	3.65	277	136,200
33	42	3.70	269	132,400
32	41	3.75	262	128,800
31	40	3.775	258	126,700
30	39	3.80	255	125,300
29	38	3.85	248	121,900
28	37	3.90	241	118,700
27	36	3.95	235	115,500
26	35	4.00	229	112,700
25	34	4.05	223	109,700
24	33	4.10	217	106,900
23	32	4.15	212	104,200
22	31	4.20	207	101,600
21	30	4.25	201	99,000
20	30	4.30	197	96,800
19	29	4.35	192	94,400
18	28	4.40	187	92,200
17	27	4.425	185	91,100
16	27	4.45	183	90,000
15	26	4.50	179	87,900
14	25	4.55	174	85,800
13	24	4.60	170	83,900
12	23	4.65	167	82,100
11	23	4.675	165	81,800
10	22	4.70	163	80,100
9	..	4.75	159	78,300
8	..	4.80	156	76,600
7	..	4.825	154	75,000
6	..	4.85	152	74,700
5	..	4.90	149	73,300
4	..	4.93	147	71,900
3	..	4.95	146	71,700
2	..	5.00	143	70,200
1	..	5.03	141	68,900
0	..	5.05	140	68,700

CONVERSION TABLE II

Rockwell B scale	Scleroscope Model C	Brinell Millimeter diam. 10 Millimeter ball 3000 kilograms	500 kilograms	Brinell Numbers
100	41	4.00	....	229
99	..	4.05	....	223
98	..	4.08	....	219
97	..	4.13	....	214
96	..	4.17	....	210
95	..	4.22	....	205
94	..	4.27	....	200
93	..	4.30	....	197
92	..	4.35	....	192
91	..	4.40	....	187
90	40	4.45	....	183
89	..	4.50	....	179
88	..	4.53	....	176
87	..	4.57	....	172
86	..	4.62	....	169
85	..	4.67	....	165
84	..	4.72	....	162
83	39	4.75	....	159
82	..	4.80	....	156
81	..	4.84	....	152
80	..	4.87	2.05	151
79	..	4.92	....	148
78	..	4.97	....	145
77	..	5.02	2.10	142
76	..	5.05	....	140
75	38	5.08	....	138
74	..	5.12	2.15	136
73	..	5.16	....	133
72	..	5.20	....	131
71	..	5.25	2.20	128
70	..	5.30	....	126
69	..	5.33	2.25	124
68	37	5.37	....	122
67	..	5.41	....	120
66	..	5.45	2.30	118
65	..	5.48	....	117
64	36	5.52	....	115
63	..	5.56	2.35	114
62	..	5.59	....	111
61	..	5.64	2.40	109
60	35	5.67	....	108
59	..	5.71	....	107
58	..	5.75	....	105
57	34	5.78	2.45	104
56	..	5.82	....	102
55	33	5.85	....	101
54	..	5.89	2.50	99
53	32	5.92	....	98
52	..	5.97	....	97
51	..	6.00	2.55	96
50	31	....	....	95
49	..	....	....	94
48	30	....	2.60	92
47	..	....	....	90
46	29	....	2.65	89
45	..	....	....	88
44	28	....	....	87
43	27	....	2.70	86
42	..	....	....	85
41	26	....	....	84

(Continued)

CONVERSION TABLE II (Continued)

Rockwell B scale	Scleroscope Model C	Brinell Millimeter diam. 10 Millimeter ball 3000 kilograms	500 kilograms	Brinell Numbers
40	25	....	2.75	83
39	..	....	....	82
38	24	....	....	81
37	23	....	....	..
36	22	....	2.80	80
35	..	....	....	79
34	21	....	....	78
33	20	....	2.85	77
32	19	....	....	76
31	..	....	....	75
30	18	....	2.90	74
29	17	....	....	..
28	16	....	....	73
27	15	....	2.95	72
26	..	....	....	71
25	14	....	....	70
24	13	....	....	..
23	12	....	3.00	69
22	..	....	....	68
21	11	....	....	..
20	10	....	2.05	67
19	...	....	....	66
18	..	....	3.10	65
17	..	....	....	64
16	..	....	3.15	63
15	..	....	....	62
14	..	....	3.20	61
13	..	....	....	60
12	..	....	3.25	59
11	..	....	....	58
10	..	....	3.30	57
9	..	....	....	56
8	..	....	3.35	55
7	..	....	....	54
6	..	....	3.40	53
5	..	....	3.45	52
4	..	....	....	51
3	..	....	....	..
2	..	....	3.50	50
1	..	....	....	..
0	..	...	3.55	49

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Dr. R. W. Woodward, formerly of the Bureau of Standards, now with the Whitney Mfg. Co. of Hartford, Conn.
Mr. H. W. Staples, Metallurgist of the Bristol Brass Corp., Bristol, Conn.
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The information conveyed in Technologic Paper No. 11 of the Bureau of Standards has been used as a basis for conversion data.

THE MANUFACTURE AND PROPERTIES OF WROUGHT IRON

By James P. Baldwin

THERE are two principal methods which may be used for the manufacture of wrought iron, the first being a direct process by reduction from the ore, and the second, and indirect process based on the refining of pig iron. The latter is by far the more important, but the first, since it has an historical value, will be briefly described.

The production of simple malleable iron direct from ore began among the ancients and was accomplished by heating iron ore in the presence of a reducing agent, such as charcoal, in an open fire. As time passed these iron masters went to the hill top where they could take advantage of the strong winds to produce results in shorter time. The use of chimneys, followed by short stacks with artificial blast, still further increased their output. Finally in Catalonia, a province of Northern Spain, the Catalan forge was developed which had no essential difference from the cruder appliances used except that by means of a blower called a "trompe", an air blast of 1 1-2 to 2 pounds per square inch was developed and production amounted to about 300 pounds of iron in six hours. The American Bloomery followed and altho it was restricted to the use of magnetic iron ore finely divided, it produced larger quantities than the Catalan Forge; its principle was the same and varied only in the fact that the sides of the hearth were water cooled and that pressure was produced by means of steam or by a water-wheel.

Attempts to produce wrought iron direct from ore commercially have been many, but without any permanent success so that today the indirect pig-boiling or puddling process is the prevailing method. The pig iron used is known as "forge iron" or "mill iron" and while different mills vary widely in their specifications for their pig iron, the following represents average practice:

Carbon	not specified
Phosphorus	less than 1.00 per cent
Sulphur	not over 0.1 per cent
Silicon	0.75 to 1.25 per cent
Manganese	0.50 to 1.00 per cent

The presence of some silicon is necessary to the proper working of the puddling process but excessive amounts should be avoided because of the unnecessarily large amount of iron that will be slagged off. Too high or too low silicon results in longer time per heat. Some phosphorus is an advantage as it tends to increase the yield and prevents the slag from getting too thick at the end of the operation, while on the other hand too much of this element leads to a waste of iron, and makes it almost impossible to produce a good structured iron. Sulphur should be low permitting the removal of most of it before the burning of the carbon, thereby prolonging fluidity and thus aiding the removal of phosphorus and sulphur.

The puddling furnace has changed but little in its essentials since the invention of the process of Joseph Hall in 1830. It is a single-bedded reverberatory furnace, lined externally with plates bound together with rods and provided with stoke holes for firing when coal is the fuel and a working door, or sometimes two, one on either side of the

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hearth. It is lined internally and roofed with fire-brick. The hearth is oblong in form and the sides and bottom are covered with a layer of nearly pure oxide of iron called "fettle." The size of the furnace depends on the ability of the puddler to reach the different parts of the furnace hearth and exert effective force therein. Its capacity varies from 500 to 1500 pounds per heat, the usual size being from 900 to 1200 pounds. The lining of the hearth, or bottom, may be made from roll scale, iron ore, puddle cinder, or a combination of these in various proportions, practice differing in the various works. The resulting fettle is roughly classified under three heads, fusible, moderately fusible and infusible. Generally speaking the infusible kinds are more costly and contain fewer impurities. In the fusible class we have as representative the slag taken out of the puddle ball at the squeezer, which is somewhat purer than the slag which runs from the furnace during the "boil". "Bull dog" or calcined tap cinder is a type of the partly fusible fettle. Infusible fettle is composed of ferric or magnetic oxide of iron.

In commencing work with a furnace the first object is to get a good firm bottom. This is done by covering the cast iron plates which form the bottom with refractory fettle and roll scale and then lighting the fire, getting enough heat to cause good coherence of the mass. Scrap iron is sometimes added, raised to a welding heat and worked around the various parts of the hearth to aid the production of a good sound mass. The bottom must be kept in good order so that when working the furnace the melting pig does not come in contact with the cast iron plates which would be eaten through. After the bottom is made, low walls from the same material are developed in order to form a basin for the working of the metal.

The pig iron is hand-charged through the working doors of the furnace and vigorously heated for the first half to three-quarters of an hour in order to melt it down rapidly. During this period most of the silicon and manganese are removed as well as a considerable quantity of phosphorus and sulphur. This is followed by charging roll scale or iron ore to produce a basic slag and the fire is damped and sometimes even a tin or so of water is thrown on the bath to bring down the temperature. This is done for the purpose of bringing the temperature to a point where phosphorus and sulphur will be removed before the carbon. As is well known, the purer the iron the higher its melting point which means that if the carbon were burned out ahead of the other impurities, a pasty mass of metal would result which would be high in phosphorus and sulphur, a result highly undesirable. When the carbon begins to oxidize, light blue flames of burning carbon monoxide breaks through the slag, occasioned by the following reactions:

$$Fe_2O_3+3C=3CO+2Fe.$$
$$CO+O=CO_2$$

Unless the slag is very basic at this point the carbon monoxide may reduce the phosphorus and sulphur causing them to go back into the metal. Some mills practice the use of soda ash (commercial sodium carbonate) to render the slag more basic and fluid. As this formation of CO progresses, the metal begins to boil, the mass swells and about half of the slag content of the furnace flows out of the cinder hole into a slag buggy. The boiling lasts 20 to 30 minutes and while it is in progress the puddler and his helper rabble the contents of the furnace with hoe-like bars to keep the bath uniform, to keep the iron from settling

on the bottom and to bring the entire mass of metal in contact with the slag for the removal of impurities. Toward the end of the boiling, which indicates the removal of nearly all the carbon, the metal "comes to nature" and points of solid metal project up thru the slag and collect on the bottom. This must be remedied in order to prevent the loss of metal, chilling of iron on the bottom and unevenness in composition. When the entire mass has come to nature the puddlers begin to work the metal into balls of about 150 to 175 pounds in weight, using their rabbles and placing the balls near the bridge wall to keep them hot and the slag fluid until they are removed. When the metal is entirely "balled" the balls are removed, one at a time, and dripping with slag, are carried with wide-jawed, long-handled tongs suspended from a monorail, to the squeezer.

The squeezer consists of an outside-corrugated, rotating cylinder set off-center inside of another stationary cylinder, inside-corrugated and having an opening in its side from top to bottom for the entrance and removal of the puddle ball. The result of the action of the squeezer is to knead and elongate the puddle ball as it is carried around by the rotating cylinder, its form when leaving the squeezer being that of a rough cylinder of about 14 inches to 18 inches in diameter and from 24 inches to 36 inches long. This is passed through puddle rolls, coming through as "muck bar", having a cross section of about ⅝-inch x 4-inch, though this varies according to the practice of each individual mill and the purpose for which the metal is intended.

The muck iron passes on to a roll table which carries it to the shears where it is cut into lengths of about 2½ to 3 feet. It is then sprayed with water to cool it, piled by laying succeeding layers at a right angle to the layer immediately beneath, tied with wire, raised to a welding heat and rolled again, making what is known as single-refined wrought iron. If this product is treated to the above operations of piling, tying, heating and rolling a second time, it is known as double refined iron. The time required for a complete cycle of the above operations is from 1¾ to 2¼ hours.

In addition to the above method, a large tonnage of so-called wrought iron is produced by breaking up iron pipe by means of drop hammers, mixing other iron scrap with it, piling it, raising it to a welding heat and rolling it. This results in an inferior product but is used for the less important products.

The fuel used is usually bituminous coal which burns with a long flame. Some plants have been using powdered coal with marked success while others have had good results from oil fuel. The loss of heat from the waste gases is often prevented by placing a boiler over the puddle furnace and conducting the hot gases through it before passing them to the stack.

Losses incurred in the puddling process due to oxidation of impurities and some slagging off of iron, run from 4 to 8 per cent of the weight of the metal charged. The amount of slag produced varies directly as the silicon content of the charge and runs from ¼ to ½ of the weight of the metal placed in the furnace.

Many efforts have been made to puddle mechanically but the furnaces designed with this end in view have not been a success and hand puddling continues, and probably will continue in the future, to be the usual practice. One advantage of the puddling process is the

ability to deal with widely varying irons but each individual mill should adhere very closely to the use of one kind of iron because a change in its composition causes the metal to work differently, causing confusion among the puddlers until they become accustomed to the working of the new iron.

The chemical composition of bar varies widely depending upon the use to which it is to be put. If it is to be used for crucible steel, its composition would be about as follows:

Carbon	0.05—0.15 per cent
Phosphorus	0.010—0.020 per cent
Sulphur	0.010—0.020 per cent
Manganese	0.05—0.10 per cent
Silicon	0.10—0.30 per cent

If the muck bar is to be piled and rolled into refined iron, the resulting product may contain about 0.020 per cent to 0.030 per cent sulphur and phosphorus between 0.075 per cent and 0.200 per cent manganese and carbon being about as above. Finished wrought iron, double-refined, has a composition about as below; although different from steel, the character of wrought iron is not easily predicted from its chemical analysis:

Carbon	0.05—0.10 per cent
Phosphorus	0.10—0.30 per cent
Sulphur	0.020—0.040 per cent
Manganese	0.02—0.10 per cent

It should be noted that the practice of puddling varies rather widely and this has a direct influence on the composition of the final product; the above figures are, therefore, only average.

Concerning the physical properties of wrought iron, it may be interesting to note the following figures taken from Turner's "Metallurgy of Iron", which not only give one an idea of the effect of mutliple refining on the strength of wrought iron but also to hold out a warning that it is possible to carry the refining too far:

	Tensile Strength Pounds per square inch
Original puddle bar	44,000
2nd working	53,000
3rd working	60,000
4th working	60,000
5th working	57,000
6th working	62,000
7th working	60,000
8th working	57,000
9th working	57,000
10th working	54,000
11th working	52,000
12th working	44,000

As a general rule it is of little advantage to carry the refining beyond "double-refined" iron. The tensile strength of wrought iron varies from 36,000 to 60,000 pounds per square inch, depending on its composition, its refining size of test piece, etc. The elastic limit runs from 24,000 to 32,000 pounds per square inch. Per cent elongation varies from 15 to 25 per cent, while the reduction area usually lies between 40 and 50 per cent for the better grades. The latter quantity is a safe

guide to the probable quality of the iron as poor iron with equal strength will often show only 30 per cent reduction of area.

If a longitudinal section of a piece of wrought iron be examined under the microscope it will be found that it consists of grains of commercial ferrite, carbonless iron, containing phosphorus, sulphur, etc., as impurities, crossed by irregular dark bands of slag, elongated in the direction or rolling. A transverse section shows these particles of slag as rounded spots, being cross sections of the bands in the longitudinal section. The ferrite is of the same appearance in both longitudinal and transverse sections and explodes the theory that wrought iron has a "fibrous" structure. The slag contained in the metal is composed of both ferrous and ferric oxides, silica, oxide of manganese and phosphorus pentoxide.

The resistance of wrought iron to corrosion is remarkable: at Delhi, India, there is a column of this material weighing more than six tons which is about fifteen hundred years old.

Wrought iron has a corded appearance when nicked and bent to destruction, due to the bands of slag contained in it. The metal welds nicely although close control of the temperature is necessary with the better grades. Its superiority over steel for withstanding alternating bending stresses is well established.

LOCAL HARDENING OF EXTRUDING DIES

By Edwin H. Barker

THE designer of special tools for many types of automatic machines, finds that his work is daily becoming more complex. He must adapt his tools to the machine available for the job and he must make them as nearly fool-proof as possible, and, above all, he must make them turn out perfect work twice as fast, as would have been considered reasonable a few years ago. In many cases the machines available have been hastily designed, and have such a narrow field of use, that much faulty design persists, through lack of sufficient competition among the manufacturers to stimulate improvement. Given these conditions, the tool designer must call to his aid a wide range of tool steels, and the most careful and accurate methods of heat treatment available, together with highly specialized methods of application designed to meet the necessities of the various types of tools required.

Fig. 1-a shows a set of tools for a semi-automatic cap press, designed for the manufacture, in one operation, of caps for collapsible tubes, the blanks being fed to the die by a simple form of tube and finger mechanism. This die has been broken in half to show the construction, the blanks and finished work as it comes from the press being shown to the left of the tools.

The construction of this press is such that the high pressures necessary to form the threads and decorations of the cap, and limited by the small amount of support the die has where it is held in the counter-bored die slide of the press, often caused the dies to burst when operating at high speed. A die broken in this manner is shown in Fig 1-b.

It is necessary to keep a high polish on these tools, both for the appearance of the product, and for the proper operation of the tools, therefore a steel must be used which is hard, close-grained, capable of taking and retaining a high polish against the abrasive action of the flowing metal, and yet not be too brittle to withstand the pressure necessary to hold the lower gate in contact with the die against the action of the punch. Obviously, as it is not easily possible to increase either the thickness or diameter of these dies, owing to the light construction and crowding of the parts of the press, the solution of this problem lies in the local hardening of those surfaces exposed to wear, while retaining the toughness of the softer steel in the rest of the die. The methods of local hardening which are to be described, not only meet this requirement, but enable us to more thoroughly harden the internal surfaces of dies having very small apertures.

Quenching jets for obtaining these results are shown in Fig 1-c, one type for dies where all the wearing surfaces are in the bore, and the other where a portion of the face of the die as well as the bore is exposed to abrasive action. The holes can be clearly seen in the photograph. Fig. 1-d shows three types of jets used in the hardening of extruding dies for the manufacture of collapsible tubes, dispensing bottle tops, etc. It will be noticed that the one to the right has a central opening closed by a screw, which may be removed to permit the addition of a jet for the deep hardening of dies for tubes with long conical necks. Special attention is directed to the jet on the left, which is used in quenching closed end dies where only the bottom and walls must be glass hard, and the diameter of the opening is not over 0.250 inch. In quenching the heated die is inverted over the jet

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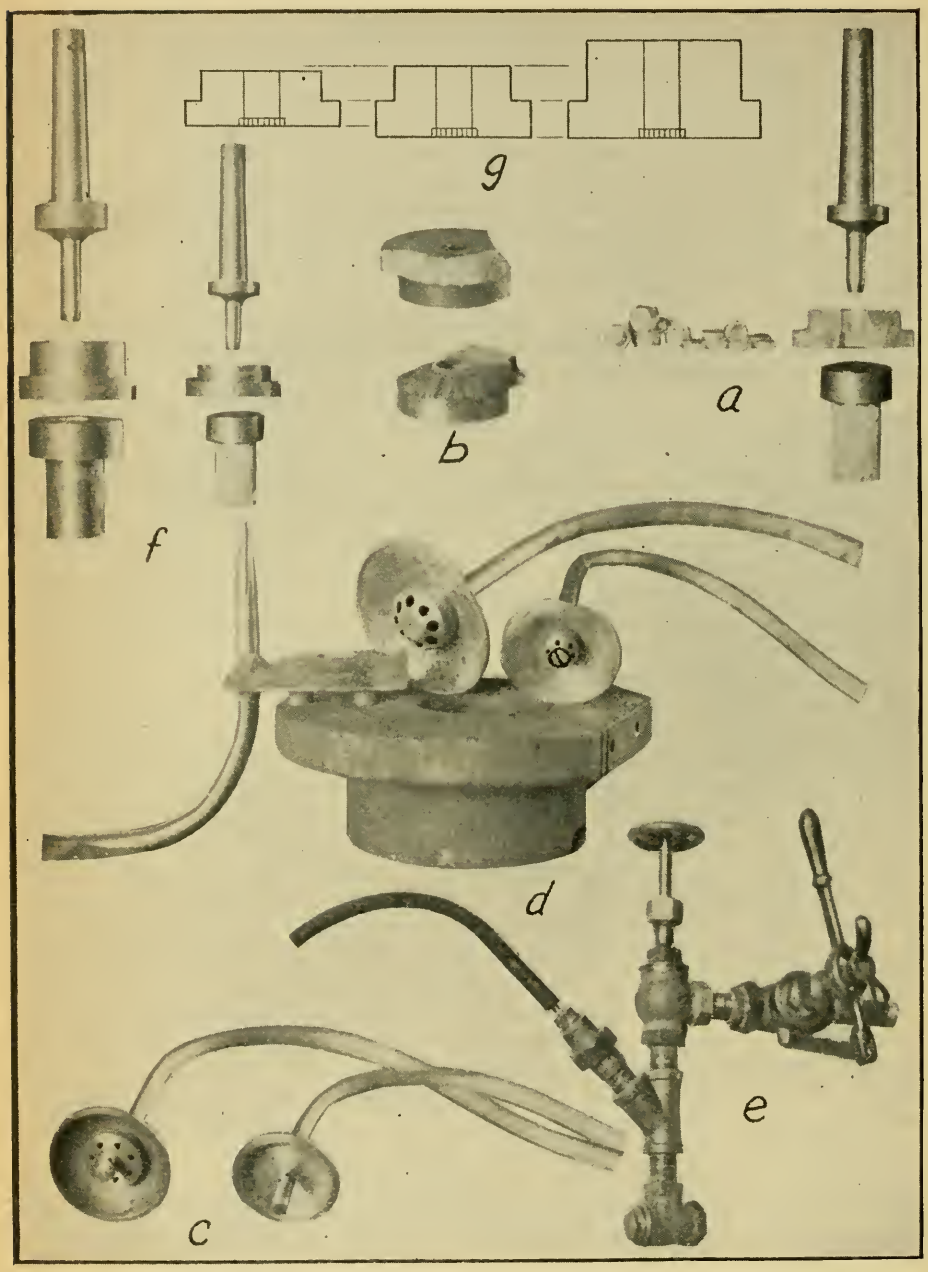

Fig. 1—*a*. Shows a set of tools for a semi-automatic cap press. The die has been broken to show its construction. *b*. A die broken as the result of improper support to withstand the excessive pressures needed to form the threads and decorations of the cap. *c* and *d*. Shows quenching jets for hardening dies. *e* Shows the quick acting control valve. *f*. Shows a comparison of the dies for a large and a small sized press *g*. Shows a comparison of the shoulder and body of large and small dies.

and the full pressure applied as quickly as possible. The water is driven out along the spiral grooves and the centrifugal action thus set up prevents the formation of steam or air pockets in the die. These jets are supplied with water at about 50 degrees Fahr., under pressure of 60 pounds per square inch, and are controlled by a quick-acting lever gate-valve which will be described later. The form of shield shown, has proven very satisfactory; the results showing a gradual tempering of the die from the almost glass hard center out towards the soft exterior, which provides sufficient stiffness to prevent distortion, with toughness necessary to prevent bursting. The construction of these jets is very simple, and the forms required to quench special shapes of dies can be quickly made. The supply tube is made of copper, the shield is hammered or pressed from 1/16-inch sheet copper, and the head is turned from a brass bar of suitable diameter, drilled and counterbored to receive the end of the supply tube, and the whole fixture is assembled and securely soldered in place. All jets designed for quenching dies of circular section, should have the jet-holes bored tangentially, as this will set up centrifugal action and thus insure the closest possible contact of the water with the steel.

The control valve used, is so designed that all sizes and types of jets are attached interchangeably. It has several unique features which have been developed to eliminate small leaks, which seems to be the tendency of nearly all quick acting valves.

Fig. 1-e shows the control valve. The water enters through the quick acting lever gate-valve, passing through the angle valve, which is used to reduce pressure when necessary, down to the Y on the side outlet, to which is attached the rubber tube carrying the jet. The lower opening of this Y terminates in a bronze ball angle check valve. The whole fixture is set on a slight angle, so that the ball of the check valve tends to fall away from its seat. This allows all small leakage, as well as the water in the jet, rubber tube and fittings to drip away. When, however, the full force of the water is turned on this ball is forced against its seat, and the full stream is diverted through the branch of the Y to the jet. This device has entirely overcome the formation of soft spots in dies, caused by stray drops of water falling on the work ahead of the full supply necessary to efficient quenching.

If we may return to the consideration of the cap dies for a moment, you will see in Fig 1-f a comparison of the dies for a larger size press, with the small size. The builders of this machine, at our request, increased the proportionate thickness of the die slide, making possible the use of the die shown. The increased life of dies of this larger size more than justifies this change of design. A die similar to the one shown has been in continuous service for several months, and has just been condemned with a record of 1,200,000 pieces. It is obvious that the larger mass of this die, parallel to the greatest pressure exerted against it, makes possible the use of a harder closer-grained steel than we have been able to use successfully in the smaller size, without running the risk of bursting under the pressure developed at the hight speed of production maintained. The results with this press were so encouraging that we rebuilt several of our small machines to take our medium standard size dies. This change entailed a considerable outlay of money.

In Fig. 1-g it will be noted that the designer of the large size die failed to increase the shoulder in proportion, even to the small size die, while we,

(*Continued bottom Page* 1042)

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

The answer to Question No. 24 published in the July TRANSACTIONS contained the tabulated analysis of the steel which was used in carrying out these experiments. Our attention has been called to the fact that the silicon content is in error.

Complete anlysis should be as follows:

	Per Cent
Carbon	0.15 to 0.20
Manganese	0.35 to 0.65
Phosphorus, below	0.040
Sulphur, below	0.040
Silicon	0.05 to 0.10

(*Continued from Page* 1041

profiting by many costly failures, have materially cut down the body of the die in proportion to the shoulder. This size die is made of the same steel as the larger size, and shows at least equal efficiency. The heating of all of these tools is accomplished in a special type electric furnace. This furnace is equipped with a pyrometer system which indicates when the die which is being heated passes through the critical range of temperature. Very satisfactory and uniform results have been obtained with this heat treating equipment.

In conclusion, a word regarding methods of keeping records of manufacture and production of tools, and the condition and proportionate production of the presses. The tool symbol, serial number, bar number of the steel, and initials of the toolmaker are stamped on the tool itself; all other details being added to the record card as the work is completed. The tool is then listed as ready for production. A daily record of production of each press is kept, showing the comparative performance of each machine; as well as the tool production, which is transferred to the tool record at the end of each period of continuous use. The daily press records serve to show when a machine is falling below its proper production, and inspection as to the cause is followed by the issue of a damage report covering the repairs necessary. The analysis of these reports and records has made possible the separation of failures due to faulty design from failures due to lack of proper alignment in the presses in a very satisfactory manner.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 37. What is the role of vanadium in steel?

QUESTION NO. 38. What regulations are recommended to reduce the fire hazzard of quenching tanks?

QUESTION NO. 39. What happens to a piece of steel when it is tempered or drawn back after quenching from above the upper critical point?

QUESTION NO. 40. What is the influence of a low percentage copper content in steel?

OLD QUESTIONS AND ANSWERS

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 12 How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

ANSWER. When a casting such as an automobile cylinder block cools down in its mold from the molten condition, cooling strains are set up within the casting due to the shrinkage of the metal during solidification, also frequently there is a chilling effect due to the contact of the metal with the mold walls, this causing an increased hardness of the surface metal which is usually difficult to machine. It is the practice of many automobile companies to accumulate motor block castings and store them in the open for suitable periods of time. This storage in the open permits of rusting and this rusting or ageing relieves the surface hardness as well as the casting strains, so that when a cylinder block is machined and the bores ground, it will not change its shape. Weathering castings is a long procedure requiring from 1 to 2 years and in many cases it is impossible for manufacurers to accumulate weathered castings in sufficient quantities to meet their production demands, therefore the expedient of annealing castings to accomplish the same effects have been used extensively. Numerous investigations have been conducted, first to determine the correct time and temperature required for annealing gray iron castings; second, to determine the effect of annealing on the physical properties; third, to determine the effect of annealing and quenching on the physical properties. It has been shown in several investigations that a temperature of 1150 degrees Fahr. is suitable for annealing to relieve casting strains. Annealing at lower temperatures than this apparently does not materially reduce the strength of the casting nor its

hardness. In order to increase the machinability it has been found that temperatures ranging from 1450 degrees to 1550 degrees Fahr. have proved sufficient although annealing at these temperatures seems to reduce the strength of the casting. The time for the satisfactory annealing of castings seems to be approximately one hour as compared with many months of weathering. The rapidity of cooling from the annealing temperature apparently has little effect.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree

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QUESTION NO. 26. Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 30 How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION NO 31. What is the effect of oxidizing gases at low pressure on heated iron?

ANSWER. By Prof. H. C. H. Carpenter and Miss C. F. Elam in a paper presented before the annual meeting of the Iron and Steel Institute, May 1922. This paper was entitled the "Effect of Oxidizing Gases at Low Pressures on Heated Iron." The following is a reprint of this paper:

The experiments to be described in this paper originated in the following way. The authors were experimenting with the vacuum etching of copper which was heated in a silica tube, at temperatures in the neighborhood of 1000 degrees Cent. The metal evolved a considerable volume of gas which, if allowed to remain in the tube, caused it to blister. If, however, the gas were pumped off as soon as it was evolved and the vacuum maintained, the copper remained bright and quite free from oxidation. Under these conditions the structure of the copper grains was rendered manifest by what may be termed a heat etch. It so happened that on one occasion Armco iron was placed in the tube with the copper, although not in contact with it. The tube was then evacuated and heated to about 1000 degrees Cent. The gas evolved from the two metals was not pumped off, but allowed to accumulate in the tube. At the conclusion of the experiment, when the metals were withdrawn from the tube, it was found that each of them had altered considerably in appearance. On the one hand, the copper was found to have become coated with a layer of blue cuprous oxide, which in some places covered the metal completely, whereas in others it took the form of six-pointed stars deposited on the metal. On the other hand. the iron was distinctly lustrous, if rather dark, and appeared to be very deeply etched. Both specimens had been originally polished and sufficiently etched to show the outline of the crystal grains.

An experiment was then made by heating the iron itself in the absence

of copper, and tests were made with Armco iron, electrolytic iron, and Swedish iron. In each case a considerable volume of gas was evolved, but no etching effects were produced and the iron appeared to be slightly oxidized. The characteristic etching effect observed in the previous experiment therefore was evidently due to something evolved from the copper.

A series of experiments was then instituted to study the progress and characteristic features of the etch produced on the iron when heated with copper. In all these cases the metals were separated from one another in the tube. The structure of the iron as revealed under the microscope was found to depend both on the period of heating and the temperature. After short periods, such, for instance ,as half an hour, at 1000 degrees Cent., the surface was found to be covered with small, somewhat irregular facets, whose orientation was constant on any one crystal but differed as a rule on passing from one crystal to another. Fig. 1 shows the structure at 300 diameters of the surface of the copper. This is hardly etched at all, although evidences of twin crystals are manifest. In the center is a blue star of cuprous oxide of very characteristic appearance ,and deposits of this constituent are also visible in other parts of the field shown. Fig. 2 shows at 300 diameters the appearance of the surface of the iron after the above treatment. Portions of three grains are visible. On each of them will be observed characteristic facets which are constant in direction on any given crystal, but vary from one crystal to another. There are also decided differences of level between the tops of the facets of the adjacent crystals. Steeply sloping surfaces connect one grain with another, and these slope to different extents. Between one crystal and another the etching is so deep as to produce what may be called a valley.

The differences of level on passing from one grain to another became still more marked as the heating was carried further. The individual facets then became larger and more regular, but the surface was rendered more uneven. Fig. 3 shows at 600 diameters the structure of Armco iron after the more prolonged etching. Regular brick-like facets are visible in the center of the field. The dark area bounding these on the right is a sloping boundary, while the facets beyond are out of focus owing to the difference of level. Fig. 4 represents at 300 diameters the structure of two adjacent grains of electrolytic iron which are much larger than those of Armco iron, and are both approximately in focus. The facets in the upper half of the field strongly suggest an orientation parallel to the cube face, whereas those in the lower half represent a section of a crystal cut obliquely. Not only were the crystals of electrolytic iron larger than those of the Armco iron, but also the facets themselves.

On heating for a longer period, say for two hours, the surface became still more uneven and was found to be covered with perfectly regular squares, rectangles, and triangles, together with other figures of less regular shape. Fig. 5 at 600 diameters is a typical example of the structures thus obtained. In the former the rectangle etch figures predominate and in the latter the triangle. In these cases, owing to the very deep etch, only certain parts of the field can be obtained in focus at any given time. It was observed that the size and general form of the figures varied somewhat in different experiments owing, doubtless, to slight differences in pressure, and to variations in the composition of the gases evolved from both metals. Occasionally very minute etched figures were obtained, such as are illustrated in Fig. 6, at a magnification of 600 diameters, which represents part of one crystal in which

the etched figures appear as minute squares and rectangles. Substantially the whole of this field is in focus. The three or four irregularly shaped figures observed are due to slight porosities in the iron.

It remains now to consider what the etched figures really represent. The authors' first idea was that the structures observed were those of the etched iron, more particularly as the form of the figures agreed very well with what is known as to the crystal form of gamma and alpha iron. It very soon became evident, however, that the hypothesis was not correct in this form. It was found that, under certain conditions, small black shining crystals were formed on the surface of the iron, in addition to the etched figures described above. It was thought that these might be an oxide, and in removing some with a penknife in order to test it with a magnet, it was noticed that the "etch" layer could also be removed, revealing unaltered iron underneath. It appeared therefore that the characteristic etch figures were due to an oxidation of the iron during heating, and that accordingly they must be ascribed to an oxide and not to the metal. General support to this view was given by the fact that the copper itself was, as has been mentioned, also oxidized, the surface in certain places being almost completely covered with the characteristic blue cuprous oxide.

Further experiments were then carried out to determine what relation the structure of the oxide bore to that of the iron. It was noticed that if the specimen were heated to 1000 degrees Cent. several times, there was no change in the shape or size of the characteristic etch figures, although it is obvious that on every occasion a change in the crystal form of the iron itself must have taken place on passing through the Ac3 inversion and back again through Ar3. In other words, it is clear that the alpha to gamma and gamma to alpha change had no influence on the facets once they had been produced. Moreover, on marking a particular area before heating it could be shown that its structure corresponded with that of the original alpha iron crystal. The boundaries were the same in both cases. On repolishing and etching after heating it bore, however, no relation to the metal underneath, which had recrystallized in passing through Ac3 and Ar3. Furthermore, upon heating the specimen of the iron below 900 degrees Cent. it developed the same characteristic etch facets as at 100 degrees Cent., although the time required was considerably longer (a minimum of two hours). It is clear therefore that the formation of the oxide begins below 900 degrees Cent. and that it takes its shape from the structure of alpha iron, and having once begun it continues to grow, regardless of the phase changes which take place in the iron underneath on passing from alpha to gamma and back again. The authors do not regard the process merely as an oxidation of the iron crystals, by means of which the structure of the iron is made manifest, so much as growth of crystals of an oxide, the orientation of which is determined by the iron on which they are first formed. In certain instances the valleys produced at the boundaries are caused by the growth of oxide crystals away from the true boundary in two directions, the slopes of the valley being made up of the "sides" of the crystals. It will be noticed that these are striated in a regular manner corresponding with the orientation of the facets observed on the surface.

The fact that one substance will assume the same orientation as that of another on which it is crystallizing, provided they are isomorphous, is well known. This was established, for example by Mr. C. V. Baker[1] in his

[1] *Journal of the Chemical Society*, 1906, vol. lxxxix. p. 1120.

experiments on "the formation of regular growths of crystals of one substance upon those of another." Parallel growth of sodium nitrate crystals on calcite surfaces are shown on Plate XX., Figs. 63, 64, and 65 of Sir George Beilby's book entitled "Aggregation and Flow of Solids." It seems probable, therefore, that in the present case the oxide first formed is magnetite

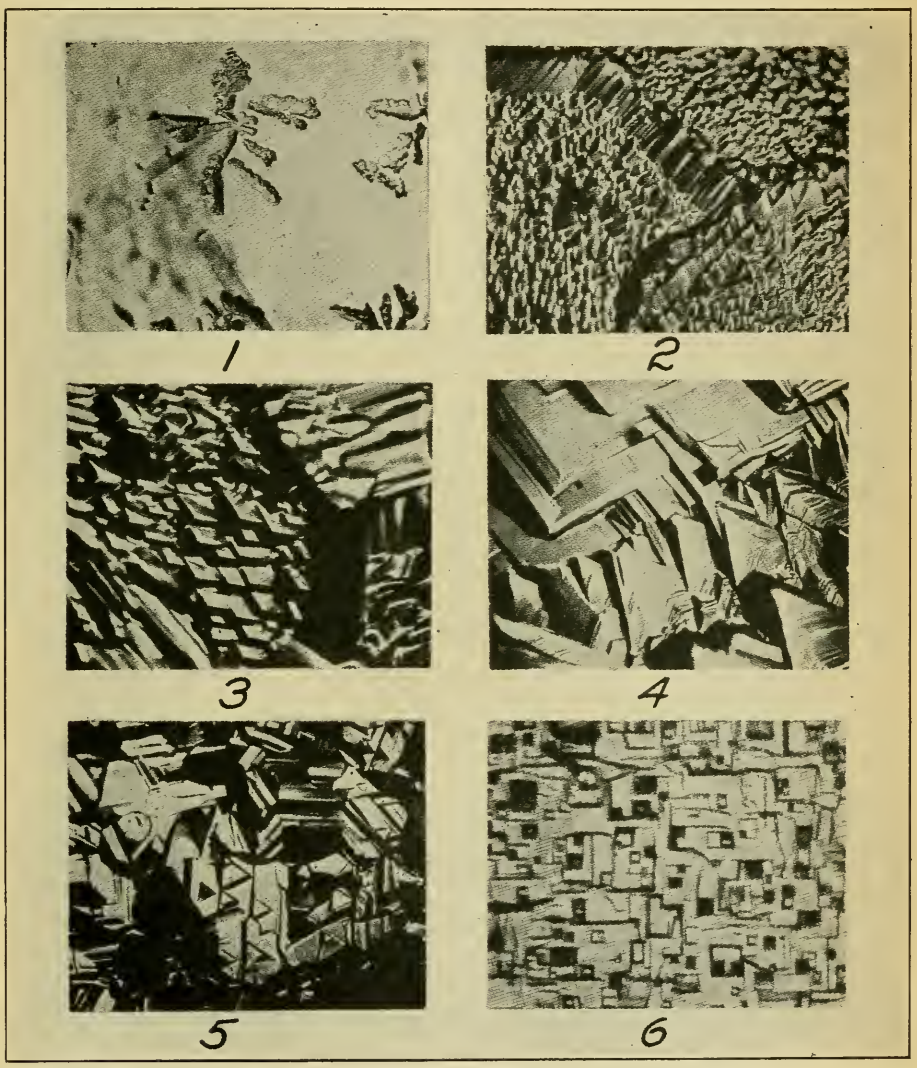


Fig. 1—Copper heated in vacuo in the presence of Armco iron. X 300
Fig. 2—Armco iron heated in vacuo in the presence of copper. X 300
Fig. 3—Armco iron after more prolonged heating. X 600
Fig. 4—Two adjacent grains of electrolytic iron after heating. X 300
Fig. 5—Armco iron after heating in vacuo for two hours, showing rectangular and triangular figures. X 600
Fig. 6—Crystal of electrolytic iron showing minute square and rectangular figures. X 600

Fe_3O_4, which has a cubic symmetry like alpha iron. The surface crystals, however, which were removed with a penknife, were not attracted by a magnet, indicating that they had been further oxidized, probably to Fe_2O_3, without

change of form. It is well known that hematite crystallizes in the hexagonal system, but this oxide has been obtained in a form pseudomorphous with magnetite by heating the latter in a blow-pipe flame for several hours. The crystals oxidized without change of form.[2] A type of structure somewhat similar to that described above was obtained by Osmond and Cartaud.[3] They heated to redness a crystal of iron (which had one of the cube faces polished) in a nickel crucible packed with calcined magnesia and covered with cast-iron shavings. To use their own words in describing the results of this experiment: "The polished face oxidized naturally and displayed square figures strongly resembling corrosion figures. .. . . It seems that the oxidation has been regulated by the structure of the metal."

As has been already stated, the characteristic structures of oxide described in the present paper are only produced under the combined influence of the gases evolved from both copper and iron. The mere oxidation of the iron which always takes place to some extent when it is heated by itself in an evacuated silica tube, does not produce these structures at all. What has to be explained, if possible, is the oxidation of the iron in a particular way under the combined influence of the gases simultaneously evolved both from iron and copper. The effects are only produced by copper containing the gases normally present in the metal. If the copper be previously heated *in vacuo* several times until no gases are evolved and be then heated with iron in an evacuated tube, it remains quite bright, while the iron oxidizes slightly without the production of the characteristic facets of oxide. Both the composition and volume of the gases contained in copper vary within fairly wide limits. Several samples of the metal, however, produced similar effects on the iron. The action therefore clearly takes place with gases whose composition varies to some extent. The gases collected when one specimen of the copper used in the authors' experiments was melted *in vacuo,* gave the following results on analysis:

	Per Cent.
Hydrogen sulphide	61.2
Carbon dioxide	34.9
Oxygen	1.1
Residual gas (nitrogen)	2.8

It is to be noted that this mixture contains only just over 1 per cent. of free oxygen, but that there is a considerable amount of oxygen present combined with carbon and sulphur. Less information exists with regard to the gases present in iron. The majority of gas analyses have been carried out on steels, and in these cases the gases appear to consist of mixtures of the oxide of carbon together with hydrogen and nitrogen. It is impossible to predict what would be the equilibrium in a system composed of the metals, copper and iron, at temperatures of from 900 to 1000 degrees Cent., which was evolving a mixture of the above types. Broadly speaking, however, it appears that under these conditions the atmosphere produced is decidedly oxidizing both as regards the copper and the iron. In their experiments the authors have noticed the deposition of free sulphur in the cooler parts of the quartz tube. This points to the decomposition of the sulphur dioxide always present in the copper, and the result would be the production of free oxygen. Another source of this gas is possibly the decomposition of some

[2] Friedel, *Bull. Soc. Franc. Min.*, 1894, vol. xvii. p. 450.
[3] *Journal of the Iron and Steel Institute*, 1906, No. III. p. 481.

cuprous oxide. The fact that the production of the characteristic facets of oxide requires a period of considerable duration for its completion is due, no doubt, to the gradual liberation of the gases over this period. Those contained in and evolved from the copper must be held to be the chief cause of the characteristic structures of iron oxide produced, but the influence of their possible inter-action with the gases evolved on heating the iron itself must not be lost sight of.

Summary

Samples of Armco, electrolytic, and Swedish iron were heated from below 900 to above 1000 degree Cent. in an evacuated quartz tube and oxidized slightly without producing any characteristic crystallographic features on the surface of the metal. If, however, a specimen of copper be introduced as well as containing the gases which are ordinarily present in the metal, a reaction sets in resulting in the gradual production and development of characteristic facets on the surface of the iron. These are due to the production of what is probably the oxide Fe_3O_4 which subsequently passes to Fe_2O_3 without change of form. The oxide of iron originally produced is isomorphous with alpha iron, and the orientation of the oxide produced on any given crytal is determined by the orientation of the alpha iron itself. It is, in other words, "a parallel growth" of the magnetic iron oxide. Once produced the form of the oxide is uninfluenced by heating the specimen to a temperature at which gamma iron is formed. A somewhat similar phenomenon was observed sixteen years ago by Osmond and Cartaud. The principal agent in the production of the characteristic facets of oxide is the mixture of gases evolved by the copper on heating.

QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?

QUESTION NO. 33. What is the role of nickel in steels?

ANSWER. From a paper by R. R. Abbott. The principal effect of alloying nickel with pure iron is to increase its tensile strength, elastic limit and reduction of area with a decrease in the percentage of elongation. This effect is the same when carbon is present and it has been found that a given amount of nickel produces about the same change in the physical properties irrespective of the carbon content. The normal effect of the addition of nickel up to 8 per cent in an iron-carbon alloy, upon its physical properties is as follows: 0.10 per cent of nickel increases the tensile strength 42 pounds per square inch, the elastic limit 40 pounds per square inch, the reduction of area 0.005 per cent and reduces the elongation 0.01 per cent. Comparing a plain carbon steel of the same analysis but without the nickel content we find that a 3½ per cent nickel steel will have an increased tensile strength of approximately 14,700 pounds per square inch, an increased elastic limit of approximately 14,000 pounds per square inch, an increased reduction of area of 1½ per cent with a decreased elongation of 3½ per cent. We find therefore that the tensile strength and elastic limit are increased by the nickel content probably due to the solid solution which has been formed between the nickel and the iron. In heating a plain carbon steel above the upper critical point, the cementite is dissolved in the iron of the pearlite during the passage through the lower critical point and this solution progressively dissolves the remaining

iron during the heating up to the upper critical point, at which point, it is all dissolved and the solution becomes homogeneous. During cooling a reverse action takes place but when nickel is present, this separation of the cementite from the iron-nickel solution does not progress as completely nor as easily from a plain iron solution and therefore the pearlite areas in the nickel steel are larger and much more poorly defined than in the case of a similar steel without nickel. The effect becomes more marked with rapid cooling and since the pearlite areas are considerably stronger than the iron areas, we find that in practice any nickel steel compared to one without nickel when air cooled will have a greater increase in tensile strength than the figures quoted.

Nickel also lowers the critical points upon heating as well as the magnetic critical point. Increasing the nickel content of the steel the critical temperatures are progressively lowered and it is evident that finally before absorption point will reach atmospheric temperatures and we will then have an austentitic alloy. The higher the carbon content the less nickel it takes to obtain this condition. In quenching a piece of steel rapidly enough from above the upper critical point the result will be the total absence of iron as a constituent of the alloy. The martensite which is thus produced has physical properties quite different from the mechanical mixture present before heating. A martensite containing nickel has a higher tensile strength than elastic limit but a slightly lower reduction are and elongation than in a similar one without the nickel. A heat treated nickel steel while having a somewhat lower reduction of area and elongation than a correspondingly heat treated plain carbon steel it has more than enough increase in strength to compensate for it. In other words, with a given strength nickel steel will have a greater degree of toughness. If we increased the strength of the alloy by means of nickel the loss in reduction of area and percentage of elongation is far below the loss secured when the strength is increased by increasing the carbon content. In other words the nickel as a strengthening element is not accomplished by nearly as much loss in toughness as is carbon. The effect of nickel upon the tensile strength and elastic limit in the heat treated condition varies with the amount of drawing after quenching. Nickel decreases the rate at which steel will absorb carbon in the carburizing process.

QUESTION NO. 34. What is meant by the critical range or transformation in a steel?

ANSWER. During the heating of a piece of steel from atmospheric temperature through 1650 degrees Fahr., it undergoes certain changes in structure at definite points. All normal steels experience this change in structure regardless of its carbon content, although the carbon content regulates the number of changes which it undergoes. In order that these changes may be more clearly brought out, for example, we will select a 0.20 per cent carbon steel and refer to Fig. 1 in tracing this change during heating. Assuming that the steel with which we are working is in a normal condition consisting of approximately 25 per cent pearlite and 75 per cent free ferrite we will consider the influence of the critical temperatures or critical range upon the structure of the specimen. As the specimen is slowly heated, very little change in its structure occurs until it reaches the critical point shown as Ac 1. As the heating is continued a complete change in the structure of the pearlite is noted, the pearlite being converted into a new constituent with new characteristics

and is known as austenite. The excess ferrite remains in the unchanged condition. As the heating is continued, the austenite or solid solution of iron and carbon begins to absorb the free ferrite—this condition continues until the upper line Ac 3 is reached. At this point the remaining free ferrite is absorbed by the austenite so that the structure of the steel above its upper critical point is composed entirely of the solid-solution austenite. The zone or range between the lower critical point designated as the line Ac 1 and the upper line designated as Ac 3 constitutes the critical range of this particular steel. Combined with these changes in structure there are certain allotropic changes in the ferrite. Ferrite in its normal condition is known as alpha ferrite, being very ductile and having magnetic properties. During the heating above the lower critical point and passing through the critical point shown as line Ac 2, the ferrite undergoes a change whereby it becomes practically non-magnetic and is called beta ferrite. As the temperature is increased above the upper critical point designated by line Ac 3 there is still another change in the allotropic form of the iron which is known as

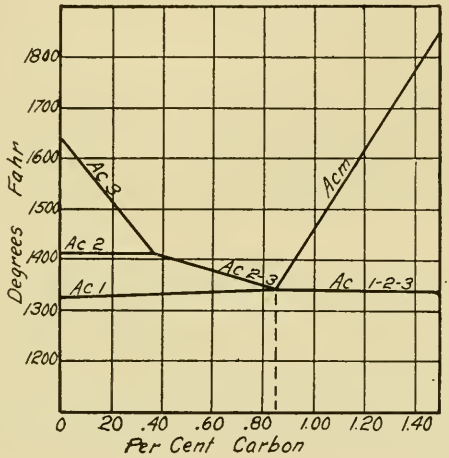


Fig. 1. A portion of the Iron-Carbon Diagram

gamma ferrite. When the ferrite is in the gamma state it has the ability of dissolving carbon or iron carbide.

Steels varying in carbon content, from practically no carbon up to 1½ per cent, each have their characteristic critical temperature changes upon heating as well as upon cooling. In plotting the points obtained in the examination of steels of various carbon contents, the composite diagram such as shown in Fig. 1 would be the result. However, this diagram is only a partial diagram of the iron-carbon equilibrium diagram. Therefore in considering any steel of specific content its critical range on heating is shown between the lower line Ac 1 and the upper line Ac 3 which merges into line Ac 2-3 at about 0.35 per cent carbon content and at approximately 0.85 per cent carbon content it merges into one line Ac 1-2-3. The carbon contents of these steels upon cooling from above the upper critical point Ac 3 occur in a reverse order and due to the molecular inertia or lag, the critical points in cooling are somewhat below the critical points in heating, however, theoretically, these two criti-

cal points should be identical. The cooling curves are designated as Ar 1, Ar 2, etc.

These characteristics of the alloy, carbon and iron are made use of in the hardening of steels. A close relation exists between the hardening of steel and its critical points, that is in order to harden a piece of steel of a given carbon content, it must be heated through the critical range and quenched. In quenching there is a retention of the structures which give increased hardness and strength which are not possessed by the structures obtained by slow cooling from above the upper critical point.

QUESTION NO. 35. What is the difference between red annealed and blue annealed sheet steel?

QUESTION NO. 36. Can mixed lots of steel be identified with a certainty by the aid of the grinding wheel spark test?

ANSWER. The spark test method of selecting or identifying steel for industrial purposes has been used in many instances and with decided success.

The method is based upon the action of the oxygen of the air, upon the combustible element present in iron, and especially in many of the alloying elements contained in the different steels, which act explosively when heated to a temperature necessary for combustion. To produce bright sparks as the result of heating finely divided particles of metal, the heat must be intense enough to cause chemical combustion between the oxygen of the air and the particles of metal.

If a piece of iron or steel is pressed upon a high speed revolving emery wheel it will throw a great number of sparks, characteristic of the combustible elements in the metal. If it were possible to detect by the quantity or characteristics of the different sparks caused by the different elements that may be in the steel, one might be able to determine with a reasonable degree of accuracy the composition of the metal. The following descriptions of the various types of sparks observed in striking metals of varied compositions on a sharp high speed grinding wheel.

If a piece of wrought iron, free from carbon, is held against a high speed revolving emery wheel, the end of the bar will be heated by friction; as the small heated particles are thrown from the wheel they follow a straight line which becomes broader and more luminous some distance from its source of heat. If the particles are not all consumed they fall to the floor, similar to that of the meteorite or shooting star. The broadening of the streak of light is probably due to the action of the oxygen of the air, requiring some time to act. All commercial iron contains a small percentage of carbon; this will be indicated by a branching or forking of the luminous streak.

In the manufacture of steel, carbon is added to iron; therefore if we touch a piece of mild steel which contains a small percentage of carbon, the effect is at once noted by a division or forking of the luminous streak. This is probably due to the presence of carbon which is acted upon by the maximum heat of the iron spark which burns explosively, causing several breaks in the original heavy line.

With increase of carbon from .50 per cent to .85 per cent the iron spark lines diminish, becoming less conspicuous proportional with increase of car-

bon; the forking of the luminous streak occurring much more frequently, subdividing by re-explosions from the smaller particles. The lower the percentage of carbon the less forking of the heavy lines of light and the farther the sparks will be thrown from their source of heat.

In the highest grades of carbon tool steel the iron lines are practically eliminated with increase of the explosions and subdivisions, causing a beautiful display of figures. This is probably due to the iron and carbon becoming united in such a manner that they are easily attacked by the oxygen of the air. Hence the danger of burning carbon tool steel on the emery wheel and in the fire. It would be well to state here that the higher the percentage of carbon the more profuse the explosions, and the shorter the distance of the sparks from the source of heat.

Practically all high speed steel contains, in addition to carbon, other alloying elements chiefly tungsten and chromium. A noticeable fact is that this class of steel contains about .65 per cent carbon but the particles show no trace of a carbon spark whatever. It is probable that the above elements are so thoroughly combined with the carbon that they prevent its explosion or burning. Hence the metal being much more refractive it will endure high temperature without scaling or burning. Therefore, the temper is not drawn so easily as in carbon steel. It will require considerable pressure on the emery wheel to ignite a spark. Its color is a dark yellow due to the chromium and tungsten. The spark follows a straight line similar to iron except that the broad streak of light is more abrupt, with an occasional branching spark which is probably due to manganese.

The characteristic of a manganese steel spark is that it widely differs from the carbon spark in that it seems to explode at right angles to its lines of force. Each dart is divided and sub-divided into a number of re-explosions which are very distinct. An illustration of this spark can be found in cast iron, high in manganese, while the spark from manganese steel is not so distinct, yet to the trained eye it is easily recognized by its branching appearance. This is probably due to the manganese and other elements becoming so united or combined as to prevent the free explosion of the manganese.

There are many other characteristic sparks, depending upon the amount and combination of the different combustible elements in steel, but to determine the quality by the spark analysis is not at all difficult if we have a known standard sample to compare with the metal under test. In other words, this method of analyzing iron and steel is a comparative test. It is well illustrated if we touch two different grades of material to the wheel at the same time and note the difference in spark characteristic. Cast iron, however, is very difficult to determine by this method, owing to the state and combination of the carbon present. The material being very seldom of standard purity will often show scarcely any luminous sparks at all.

If the carbon is in a combined state the sparks will appear similar to those of steel, proportional to the percentage of carbon so combined.

This method of analysis can be used to advantage to detect if the surface of a piece of steel is or has been decarbonized in its annealing process or otherwise. This condition is quite noticeable in annealed tool steel. It also demonstrates why the quality of steel should not be determined by surface analysis and especially by the spark test. It will also demonstrate how much of the metal must be removed in machine operation in order to reach that

portion containing sufficient carbon suitable for hardening power. This method will also determine the opposite condition, that of carbonizing, commonly known as case-hardening. If the metal has been treated properly the spark will be proportional to the percenage of carbon present and combined with the softer stock. It will also indicate the depth of penetration of the highly carbonized portion, if one cares to destroy the sample at hand.

To give an idea of the advantages of this test, a certain industrial plant desired to have brought together some 8 tons of steel which was very badly mixed up and varied in sizes from very small pieces. The contents of the main tool room inspected and the following list, which was highly interesting resulted:

HIGH SPEED STEELS

Bar stock	19.5	lbs.
Bethlehem	34	"
Blue Chip	9.5	"
Columbia	144	"
Cutter blades	553	"
Jessup	8	"
Lathe Tools	1728.5	"
Novo	93	"
Novo Superior	37.5	"
Rex A	36.5	"
Rex AA	87	"
Red, white and blue, painted	217	"
One large boring tool, Salem	23.5	"
Short ends	299	"
*Scrap	380	"
	3669.5	"

AIR HARDENING, CARBON AND OTHER GRADES OF TOOL STEELS

Air hardening tools of different grades of stock	2100	lbs.
Carbon bar stock	2200	"
Carbon tools lathe, etc	1400	"
Carpenter's	480	"
Howe	310	"
Ketos oil hardening	720	"
Midvale	300	"
Mushett (old grade)	1100	"
Sanderson self-hardening	825	"
Scrap carbon	2000	"
	11,435	"
	3,669.5	"
Grand total amount	15,104.5	"

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

RECOMMENDED PRACTICE IN CARBONIZING. By S. P. Rockwell. Presented before the Buffalo Meeting of the American Gear Manufacturing association.

Carbonizers should not be judged by speed of penetration alone, but also on the basis of the percentage of carbon in the case and rate of change of carbon as the core is approached. Carbonizers may be classified as follows: (1) Powder materials in which generator and energizer are in powder form, (2) Pellet materials in which generator and energizer are in powder form held together by a binder, (3) Pellet material, the generator being a granual of solid carbonaceous material coated with energizer, (4) Pellet and powder material in which the generator is the pellet and the energizer is in powder form. Each type has its application and should be selected accordingly. The causes of soft spots in the case are discussed. Alloy carbonizing pots are recommended.

SELECTIVE CASE-CARBONIZING. By W. P. Wood and O. W. McMullan. *Chemical and Metallurgical Engineering,* Vol. 26, Page 1077.

Investigations were carried out to obtain if possible a preventative coating in carbonizing work which might be painted on and thus used to advantage where copper plating would not be convenient. From a large number of mixtures tried out, it was found that a mixture of ground asbestos and sodium silicate (not less than 67 per cent sodium silicate) gave good results, preventing carbonization for 24 hours at 1700 degrees Fahr. Aluminum oxide and sodium silicate gave equally good results. The coatings may be removed by dipping the pieces of steel in molten sodium hydroxide or by quenching the pieces in water. The above mixtures were not found as efficient in preventing decarbonization as in preventing carbonizing.

PROTECTION AGAINST CEMENTATION BY DIRECT APPLICATION OF A COATING WITH A BRUSH. By J. Galibourg and M. Ballay, *Revue de Metallurgie,* Vol 19, Page 222.

The use of electrolytically deposited copper as a preventative against cementation is well established. Cost and time considerations prompted investigations of other anti-cementing materials. Copper dust and varnish were found to be ineffectual. Copper dust and sodium silicate were found to work well, but the cost is high

and the material difficult to remove. Copper dust, emery powder, and sodium silicate were found to work well and the cost is considerably lower. Direct immersion of samples into solutions like Heyn's and Stead's reagent were not found to give rugged enough coatings (unless dipped in glue) to be practical.

HYDROGEN DECARBONIZATION OF CARBON STEELS WITH CONSIDERATIONS ON RELATED PHENOMENA. By C. R. Austin. Presented at the May Meeting of the (British) Iron and Steel Institute.

The experiments were carried at 680 Cent, 1000 degrees Cent., and at an intermediate temperature. The steels used were 0.40, 0.99 and 1.27 per cent carbon steels. For a given time and temperature the decarbonization was found to increase with decrease in the original carbon content of the steel. After the first 20 hours the decarbonization was found to be very nearly a straight line function of the time. In the case of the high carbon steels, columnar crystals were noted in the ferrite border, and this is attributed to the action of the gas in diffusing outward. Some preliminary experiments on the diffusion of carbon in steel were conducted. Diffusion was found to take place below the A3 point, and from this it is suggested that iron possesses some solubility for carbide of iron. Experiments on decarbonization with a temperature gradient brought out the fact that the total decarbonization was dependent on (a) the rate of removal of carbon by hydrogen, and (b) the rate of diffusion of the carbide.

INDUSTRIAL RESEARCH

CO-ORDINATING FOUNDRY CONTROL. By T. M. Avey, *Iron Trade Review*, Vol. 70, Page 1562.

In a previous article the formation and object of the Electric Steel Founders Research Group were described. The details of co-operation are given in the present article. The director makes periodic visits to each of the plants, and suggests changes and improvements. Operation reports from all departments of each foundry are forwarded to the director at regular intervals, and from this information weak points in operation are pointed out to the various members by the director.

METALLOGRAPHIC RESEARCH

THE FORMATION OF GLOBULAR PEARLITE. By J. H. Whiteley. Presented at the May Meeting of the (British) Iron and Steel Institute.

The investigations of Miers, which have shown the presence of a metastable (crystallization starts by the addition of solid phase) and a labile (crystallization starts spontaneously) region below the regular equilibrium lines in many equilibrium diagrams, offer an explanation of the formation of globular pearlite. Investigations on 0.20 carbon steel bear out the explanation. It is found that with cementite nuclei present, globular pearlite can be formed 15-20 degrees Cent. above lamellar pearlite. The later requires a certain degree of supersaturation. The presence of carbide nuclei also makes possible the accurate determination of

the Ae point. Globular pearlite is found to introduce an earlier growth of lamellar pearlite in adjoining parts of the solid solution. In low carbon steels the tendency to form lamellar pearlite is very strong even in the presence of carbide nuclei.

THE INNER STRUCTURE OF THE PEARLITE GRAIN. By N. I. Bealiew. Presented at the May Meeting of the (British Iron and Steel Institute.

The cementite lamellae are roughly parallel to each other and to the crystallographic plane of the grain. When viewed on a plane at right angles to the crystal plane, the true distance between the lamellae is obtained. When viewed on any other plane, at an angle "w" to the right angle plane, the lamallae appear further apart than they really are. Methods of measuring this angle "w" are given. Some excellent high power photomicrographs of pearlite are shown.

ON THE STEPPED A TRANSFORMATION IN CARBON STEEL DURING A RAPID COOLING. By K. Honda. and T. Hukuta. Presented at the May meeting of the (British) Iron and Steel Institute.

On rapid cooling the Ar 1 point is depressed to about 600 degrees Cent. Still more rapid cooling depresses it discontinuously to 300 degrees Cent. This (300 degrees Cent.) transformation point is considered by some to be of a different nature from the regular Ar 1. Magnetametric and dilatation curves are submitted to show that the points are of the same nature.

ON THE CONSTITUTIONAL DIAGRAM OF THE IRON-CARBON SYSTEM BASED ON RECENT INVESTIGATIONS By K. Honda. Presented at the May Meeting of the (British) Iron and Steel Institute.

Graphitization experiments have shown no justification of the double equilibrium diagram involving graphite. Recent investigations have established the validity of the gamma-delta transformation. The A2 point can be considered only as a magnetic transition, being dependent on temperature alone and not on a time factor. The A_0 or cementite transformation (215 degrees Cent.) must be considered in the category with the A2 point.

X-RAY STUDIES ON THE CRYSTAL STRUCTURE OF STEEL. By A. Westgren and G. Phramen. Presented at the May Meeting of the (British) Iron and Steel Institute.

X-Ray photograms show that alpha beta, and delta (which exists at 1425 degrees Cent.) have the same crystal structure, namely body centered cubic, while the gamma form of iron is face centered cubic. Carbon in solution is shown to have a distorting influence on the crystal lattice of iron. Cementite was subjected to a large number of tests and was found to have a very complex crystal lattice.

INFLUENCE OF GRAPHITE ON IRON. By J. W. Bolton, *Foundry,* Vol. 5, Page 436.

The changes taking place on the solidification and cooling of high carbon-iron alloys are discussed and the conditions under which graphitization takes place are covered. The influence of silicon, sulfur, and manganese on the rate of graphitization are

considered and the constitution of the individual graphite particles is given some attention. No new data is submitted. The article is illustrated with numerous photomicrographs.

TOOL STEEL

BRAND vs. ANALYSIS IN BUYING TOOL STEEL. By R. H. Davis. Delivered before Convention of the National Association of Purchasing Agents, Rochester, N. Y.

Arguments are presented for and against purchasing tool steel by composition instead of brand. It is argued that buying by composition would simplify purchasing, make uniform heat treatment possible, and cut down duplication in storing. The chief argument against buying on a composition basis is that composition and quality are not comparable properties. It is stated that there are unknown elements which go to make for quality in cutting that as yet there are no tests for.

METALLURGICAL AND METALLOGRAPHIC PRACTICE

ACCURACY IN TEMPERATURE MEASUREMENTS. By H. C. Knerr. *Forging and Heat Treating,* Vol. 8, Page 235.

A combined error of not more than 1 per cent, of the temperature read, should be tolerated in a thermocouple and measuring instrument used in heat treating steel. The potentiometer is recommended in preference to millivoltmeters for reading the E. M. F. from couples, due to their greater inherent accuracy. Bureau of Standards calibrated noble metal couples should be used for checking the accuracy of base metal couples used in the plant.

PREPARATION OF METAL FOR MICROSCOPIC EXAMINATION. By Wm. Campbell. *Chemical and Metallurgical Engineering,* Vol. 26, Page 1163.

After cutting off the specimen, the surface is roughly prepared by filing or grinding. This is followed by polishing, either mechanical or hand polishing. In this latter case, Commercial 0 and 00 and Hubert 0, 00, and 000 papers are recommended. The final polish is obtained by rouge or alumina. Picric acid (5 per cent solution in alcohol) is recommended for etching wrought iron, steel, and cast iron. Hydrogen peroxide and ammonia is recommended for copper and its alloys. Bearing metals should be etched with dilute nitric acid.

WELDING

ARC WELDING OF STRUCTURAL STEEL. By E. S. Humphreys. *Iron Age,* Vol. 109, Page 1422.

Welded joints may be produced cheaper commercially than riveted joints. Their dependability remains to be tested. Two sets of tests were run on welds. In the first, various structural shapes were welded and pulled in a testing machine. In the second set, joints of the same longitudinal dimensions but varying thickness were welded and tested. Though the data is limited, the welded joints were found to give very uniform strengths.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ANDERSON, O. L., (M-7), 3649 Canfield E. Detroit, Mich.
BERMAN, I. (M-7) 72 Farmington Ave. Hartford Conn.
BLOXTON, A. M., (Jr.-5), 4118 Chesapeake Street, Washington, D. C.
BOSTON PUBLIC LIBRARY, (Sb-7), Boston 17, Mass.
BROWNE, DE COURCY, (A-7), 120 Broadway, New York City.
BUCKMAN, H. P., (A-5), 217 Broadway, New York City.
BURD HIGH COMPRESSION RING CO., Rockford, Ill.
BUREAU OF ENGINEERING, (Sb-7), Navy Dept., Washington, D. C.
BURROWS, C. W., (M-10), 17 Nevada Street, Newark, N. J.
DAVIS, G. H., (M-7), 347 21st Street, Cudahy, Wis.
EDWARDS, C. B., (M-10), 213 Liberty Bldg., Indianapolis, Ind.
FALLEEN, G., (M-5) Rockford Drop Forging Co., Rockford, Ill.
FRENCH, SIDNEY, (M-6), 1233 Murray Ave., Milwaukee, Wis.
GIRARD, B. P., (M-6), 3210 Arthington St., Chicago, Ill.
GUSTSMIEDL, (M-7), N. Irving Ave., Chicago, Ill.
HEDIN, O. C., (M-12), 100 N. 1st St. Minneapolis, Minn.
HOGLAND F. G., (S-7), National Lock Company, Rockford Ill.
HOUGHTON, E. F., & CO., (S-7),. Philadelphia, Pa.
HOUSTON, J. R., (M-7), Ladish Drop Forge Co., Cudahy, Wis.
HOWE, M. J., (M-5), 3915 Congress Street, Chicago, Ill.
JARDINE, ROBT., (M-6), Rich Tool Company, Chicago, Ill.
JOHNSON, C. G., (M-5), 5 Winchester Ave., Worcester, Mass.
JOHNSON, JACK, (M-7), Cameron Machine Co., Brooklyn, N. Y.
KINGSBURY, A. H., (M-7), Short Hills, N. J.
LAMSON, L. B., (M-5), Emmerson Brantingham Co., Rockford, Ill.
LESSELLS, J. M., (M-5), 441 Locust Street, Edgewood, Pittsburgh, Pa.
MACLEOD, J. T., (M-5), 311 E. End Avenue, Pittsburgh, Pa.
MUDGE, W. A., (Sb-1), International Nickel Co., Huntington, W. Va.
MURPHY, J. H., (A-9), 23 Thornley Street, Dorchester, Mass.
PADGETT, A. G., (M-7), 5462 Crane Ave., Detroit, Mich.
PERRY, D. E., (M-7), 24 Huntington Ave., Shelton, Conn.
QUINN, J. M., (M-8), C/o U. S. High Speed Steel & Tool Corp., Green Island, N. Y.
RAITHEL, GEO., (M-6), 5602 Greenfield Ave., Milwaukee, Wis.
RETZLOFF, O., (M-7), Worthington Pump Corp., Cudahy, Wis.
RICH TOOL CO., (S-6), Railway Exchange, Chicago, Ill.
SMITH, E. C., (M-7), 1054 Book Bldg., Detroit, Mich.
SOCIETE DE MECANIQUE DE GENNERVILLIERS, 12 Rue D'Aguesseau, Paris, France.
STEERES, L. J., (M-7), 121 Marys' Ave., Fond du Lak, Wis.
TROENDLY, H. P., (M-6), Wm. D. Gibson Co., Clyborn & Willow, Chicago, Ill.
VOEDISCH, HUGO, (M-7), Michigan Screw Co., Lansing, Mich.
WEBBER, N. B., (A-5), 150 Congress Street, Boston, Mass.
WEBBER, R. F., (M-7), 224 "A" St. S. E., Washington, D. C.
WILLIAMS, D. R., (A-7), 262 Palace Theater Bldg., Milwaukee, Wis.
WILLIAMS, S. D., (M-5), 2409 Penn Street, Harrisburg, Pa.

MAIL RETURNED

L. ALBUS, JR., 175 Bleecher Street, Brooklyn, N. Y.
BOLTON, W. A., Room 526, Y. M. C. A., Syracuse, N. Y.
GOFF, NEVILLE, Diamond Chemical Co., 1552 East 26th Street, Cleveland, O.
JOHNSON, W. R., 200 Knapp St., Apt. 3, Milwaukee, Wis.
LEWIS, M. M., (M-6), 1400 Jones Street, San Francisco, Cal.

NICHOLS, W. H., JR., Box 41 P. E. A., Exeter, N. H.

CHANGES OF ADDRESS

BEATTY, I. N., (M-5), from 407 Evans Bldg., Washington, D. C., to 8 S. Frederick Street, Baltimore, Md.
BOHNER, C. M., from 357 E. Buchtel Ave., to 142 Conger Ave., West Hill, Akron, O.
BOOTH, C. W., from 68 Batchelder St. to 495 Union Ave., Laconia, N. H.
BRANIGAN, P., from 447 S. Beech St. to 407 W. Beard Ave., Syracuse, N. Y.
BROWN, WALTER, from Walter Brown Tool Wks., St. Louis, Mo., to Kent Owens Machine Co., Toledo, Ohio.
COLTON, H. C., from 216 Pine St. to 247 Central, Springfield, Mass.
DONELLAN, J. E., from 227 Westminster Ave., Syracuse, N. Y., to Ohio Steel Foundry Co., Lima, O.
ESSELTINE, A. B., from 2026 N. California Ave. to 5742 S. Richmond St., Chicago, Ill.
GRIFFEN, R. S., from Carbon Steel Co. to 914 Homewood Ave., Pittsburgh, Pa.
GRINNELL, A. L., from Garrick Theatre Bldg. to General Motors Bldg., Detroit.
HARRISON, O. H., from 612 15th St. to 229 London Ave., Rockford, Ill.
HENTON H. M., from 12301 Buckingham Ave. to 615 Nat'l City Bldg., Cleveland.
JOSEPH, C. F., from 7420 3rd Ave., Detroit, to 420 W. Ionia St., Lansing, Mich.
KINGSBURY, J. A., from 2002 S. Miami St. to 527 Leland Ave., South Bend, Ind.
KUMMER, R., from 469 Elliott Ave. to 2365 W. Clifton Ave., Cincinnati O.
LINDHOLM, G. F., from 4711 N. Seeley Ave. to 5308 Christiana Ave., Chicago.
MARBLE, W. H., from 619 State Theatre Bldg. to 6915 Sturgeon St., Ben Avon, Pittsburgh, Pa.
MATHEWS, F. R., from 14 Princeton St. to 22 Willard Ave., Springfield, Mass.
MEDWEDEFF, M. M., from 5014 Wesley Ave., Baltimore, Md., to 93 W. Pettibone Forty Fort, Kingston Sta., Pa.
NISBET, G. B., from 643 W. 8th St., Erie, Pa., to Box 96, Welland, Ont., Can.
OBERMAIER, J. A., from 430 S. Green St. to 141 Austin Ave., Chicago, Ill.
REIFSNYDER, CHAS., from 3408 Reach St., Philadelphia, to 934 W. Bridge, Phoenixville Pa.
SCHMALZ, D. P., from 2842 N. Campbell Ave. to 5939 Grace St., Chicago.
SELLECK, T. G., from 302 N. Pine Ave. to Room 800, 20 E. Jackson Blvd., Chicago, Ill.
SIMPSON, C. W., from 13404 Shaw Ave. to 1300 E. 134th St., E. Cleveland, O.
STIVERS, L. C., JR., from 715½ W. 4th St., Davenport, Ia., to 1st and Grant Sts., Bettendorf, Iowa.
THOMSON, W. G. H., from P. O. Box 283, Rockford, to 1455 W. 37th St., Chicago, Ill.
TOWNSEND, A. S., from 1251 E. 124th St. to 1124 E. 125th St., Cleveland, O.
WALKER, E. C., from 334 N. Grove Ave. to 932 N. Blvd., Oak Park, Ill.
WICKENDEN, T. H., from Willeys Corp., Elizabeth, N J., to C/o Zeder Skelton Breer Eng. Co., 24 Mechanics St., Newark, N. J.
WHITE, R. G., from 239 E. Erie St., Chicago, to C/o W. H. White, 56 Murrayo St., New York City.
WHITE, R. J., from 33 Alfred St. to Meredia St., Springfield, Mass.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering, Bldg., Union College.

South Bend—Second Tuesday in the month.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

CHICAGO CHAPTER

The First Annual Outing of the Chicago Chapter of the American Society for Steel Treating was held Saturday, June 10, 1922, at the Hartmann House, 23 miles northwest of the "Loop" on the Milwaukee Avenue Road. It was a stag affair. The trip was made in automobiles, transportation being provided for all by those of the members and their friends who had machines.

By 12:45 P. M. all automobiles were on their way. We were fortunate in having a splendid day, the sun shining brightly and there being just enough of a breeze to make the trip enjoyable. The route taken was north on Lake Shore Drive and Sheridan Road to Evanston, west on Dempster Road to Milwaukee Avenue, and north to the Hartmann House.

After exchanging greetings, 207 members and guests sat down to an "Honest to Goodness, old-fashioned home cooked chicken dinner, and all that goes with it; no frills, just food and lots of it." The dinner was excellent and plentiful. We took along our own music and song leader, and during the dinner there was community singing. It did not take the boys long to "warm up," and the talking and laughing that could be heard indicated that everyone was having a good time.

After the dinner, we all retired to the spacious grounds surrounding

the Hartmann House, where group pictures were taken by several of our amateur photographers. Some of the pictures are shown in this issue of the TRANSACTIONS. A prize of $5.00 given for the best photograph was won by Mr. O. T. Hegg, of the Perfection Tool Hardening Company.

An indoor baseball game was started, two teams being chosen among those who desired to play. Pitcher Guthrie was so effective for the victors that he was accused of throwing a "shine ball," with the aid of some Huber's No. 0000 French Polishing Paper.

Many of the boys strolled along the banks of the Desplaines River,

Prize Group Photograph of Chicago Chapter Outing

enjoying the natural scenery, and otherwise occupied themselves. A number of group photographs were taken.

By 5:30 the last of the mighty host were on their way back to Chicago. It was a most enjoyable outing, one to which we will all look back with happy recollections. It was so successful that we may look forward to a bigger and better one next June, when we will again get together without talking of pearlite, hardenite, etc.

Our especial thanks are due the three active members of the Entertainment Committee, namely, Messrs. Havens, Henry and Hardwicke and to the Committee on Membership and the Chairman and Secretary of the chapter. It is to them that all credit goes for the smoothness with which the affair was executed and the large attendance secured.

A NEW CLUB ORGANIZED

The Ferrite Club of Lewis Institute, Chicago, was organized May twenty-third, nineteen hundred twenty-two, by students interested in discussion of the properties of iron and its alloys. The Club was organized through the efforts of Professor John F. Keller, and has at present thirty members including three of the Institute Faculty. All members of the Ferrite Club also belong to the American Society for Steel Treating.

The object of the club is to discuss articles apppearing in various technical publications, and in the TRANSACTIONS of the American Society for Steel Treating.

The members of the club have had practical and theoretical instruction in the following subjects: foundry practice, forging, heat treating, metallurgy, and metallography. This knowledge enables the students to discuss intelligently many phases of the subject, "iron and its alloys."

The following officers were elected: Harry A. Devine, President; Harold Kaiser, Vice President; Ernest Wolf, Secretary and Lester Hessler, Treasurer.

Members of Ferrite Club recently organized at Lewis Institute

NEW YORK CHAPTER

Announcement of the names of chairman for the standing committees for the ensuing year were made and are as follows: Program Committee, Sam Tour; Membership Committee, A. H. Kingsbury; Entertainment Committee, Paul F. McGovern of the General Alloys Company, New York; Research Committee, C. E. McQuigg, General Research Laboratory, Carbide and Carbon Company, Long Island City. The executive committee is made up of the foregoing chairmen; the three officers of the chapter; the retiring chairman, George I. Norris; and three or four others still to be appointed.

The chapter's next meeting will be held the third Wednesday in September and at this meeting brief abstracts of some of the principal papers to be presented at the National Convention in Detroit the week of October 2 will be read and discussed.

SCHENECTADY CHAPTER

On the 25th of June the Schenectady Chapter held its last meeting in the Civil Engineering Building of Union College. Following the paper of the evening which was presented by Stanley P. Rockwell, Consulting Metallurgist of Hartford, entitled "Carburizing," officers for the ensuing year were elected. They are as follows:

Chairman, B. T. Perry; vice chairman, Richard Topham; secretary-treasurer, G. R. Brophy; executive committee, F. P. McKibben, Mortimer Sayre, H. W. Tymes, W. G. Freer.

The proposed program for the work of the chapter for the ensuing year will be announced later.

WASHINGTON CHAPTER

The last meeting of the chapter for the season 1921-22 was held on June 30 in the Auditorium of the New Interior Department Building. The program for this meeting was a paper by Prof. H. F. Moore of the University of Illinois, Urbana, Illinois, entitled "Fatigue of Metals." This subject covering the failure of metals by fatigue or the repeated application of stresses, offers a subject of extreme interest to the steel treater, metallurgist, designer and engineer. Prof. Moore has done an extensive amount of work in the investigation of fatigue resisting properties of many steels and delivered a very interesting paper which brought forth a great deal of excellent discussion.

MILWAUKEE CHAPTER

The Milwaukee Chapter announced the result of their annual election of officers Friday July 21st.

The slate recommended by the Nominating Committee was endorsed by the membership.

The officers for the coming year are as follows: Chairman, A. W. Lorenz; Vice Chairman, H. B. Knowlton; Secretary, H. G. Lloyd. Board of Directors, E. O. Dixon, J. Fletcher Harper, C. B. Langstroth R. J. Thurner, Hugh Rowan, Chas. Wesley, Jr.

Chairman Lorenz appointed the following committees to assist him in carrying on the work of the chapter for the new year. These committees are as follows: Program Committee, Mr. J. F. Harper, Mr. E. O. Dixon, Mr. H. B. Knowlton. Membership Committee, Mr. C. P. Langstroth, Mr. Chas. Wesley, Jr., Mr. Hugh Rowan. Entertainment Committee, Mr. R. J. Thurner, Mr. H. G. Lloyd.

Reviews of Recent Patents

1,408,686. Method and means for carburizing iron, steel, and alloys thereof. Adolph J. B. Bertchy, Omaha, Neb.

The method of case-carburizing, consisting in heating the treated articles to and maintaining the same at a temperature above the critical temperature for hardening the material; and supply with substantial continuity, so as to maintain about the heated articles a nearly uniform atmosphere thereof, a relatively complex hydrocarbon unstable at the maintained temperature of the articles.

1,409,119. Annealing furnace. Hugh J. Scanlon, Waynesburg, and Michael B. Kelly, Pittsburgh, Pa., assignors to American Steel Company, Pittsburgh, Pa.

In an annealing furnace, the combination of a straight-away annealing chamber having an inlet and an outlet, a heating furnace located on one side of the annealing chamber and communicating therewith, said heating furnace being located at some distance from the ends of the annealing chamber, the top of the annealing chamber sloping in opposite directions from a point adjacent the heating furnace, whereby the material on entering the annealing chamber is gradually heated, reaching the maximum temperature at, or about, the heating furnace and being gradually reduced in temperature beyond heating furnace to the outlet.

1,409,452. Machine for hardening and tempering wire. Charles D. Johnson, Worcester, Mass

The combination with a machine for the continuous drawing of wire, of a carrier for continuously receiving the wire therefrom, a frame mounted adjacent to the wire-drawing machine, a winding block at the opposite end of the frame for continuously moving the wire along the frame toward the rear, and means mounted along the frame for continuously hardening or tempering the wire delivered from the carrier while on its way to the block.

1,409,584. Annealing furnace. Charles A. Ross, Detroit, Mich

The combination with an annealing oven, a bed therein having its end protruding from the oven and providing loading and unloading platforms, an endless conveyor disposed longitudinally of bed, flat and pan like carriers on bed approximately the width of the bed and proportioned relative to the length of the oven and each other so that a carrier is at all times in the oven and another carrier on a platform, bails attached to the carriers and adapted to be connected to the conveyor, and in operating means adapted to import movement to the conveyor oven.

1,409,842. Testing machine. Louis E. Foster, Annapolis, Md., assignor to Tinius Olsen Testing Machine Company, Philadelphia, Pa.

The combination in a testing machine of a frame; a substantially U-shaped yoke slidably mounted thereon; means for reciprocating the yoke, a member also slidably guided in the frame for movement substantially in the line of movement of the yoke; with means on the yoke for gripping the ends of a test specimen and holding it in a line at right angles to the line of movement of the yoke; an other means on the member for operatively engaging the test specimen between its points of engagement by the yoke.

1,412,152. Hardening and annealing furnace. Benjamin M. Walpole, Providence R. I., assignor to National Gas Furnace Company, Providence, R. I.

An annealing and hardening furnace comprising a rotary work carrier, a liquid tank, a heat zone above said tank and a skirt extending downwardly into the tank liquid sealing the heat zone against the admission of outer air.

1,413,134. Liquid-fuel burner. William R. Purnell, U. S. Navy.

In a liquid fuel burner the combination of means adapted to conduct a fluid atomizing agent under pressure; a helical screw thread on the exterior of the conducting means for dividing the fuel into relatively thin films or streams; means to supply the atomizing agent to the conducting means; means to supply fuel to the screw thread; and a plug having a mixing chamber, a bore connecting the conducting means with the chamber, and a plurality of tangentially disposed passages adapted to conduct fuel delivered from said screw thread to the chamber.

1,414,180. Heat-treating furnace. Edgar F. Collins, Schenectady, N. Y., assignor to General Electric Company.

A furnace for heat treating small parts comprising the combination of an enclosure, charge and discharge means substantially sealing the interior of said enclosure from the atmosphere, electric resistors mounted within said enclosure for heating a charge therein, a plurality of containers therein located in discharge and receiving relation to each other, and means for tilting the containers to transfer a charge from one container to another, thereby causing said charge to receive heat uniformly throughout.

1,414,226. Electric Heating Apparatus. Wijtse Beije Smits, Dilmen, Netherlands.

An electric heater, comprising a core composed of resistance elements and clamping plates arranged in alternation, and a coating of heat-conducting material enclosing said core, said heat-conducting material having a higher coefficient of expansion than the material of which the clamping plates are constructed.

1,412,484. Heat treatment of articles of iron and steel and alloys thereof. William Morris Mordey, Westminster, England.

The heat treatment of an iron or steel article other than a rail, for the purpose of altering and improving the physical condition of the metal of which the article is composed, such treatment consisting in arranging the article in a magnetic field set up between the magnetic poles of a powerful alternate current electro-magnet so that the article will form part of the magnetic circuit of the magnet core and will have induced in it a magnetic flux and consequently eddy currents of such strength as thereby to become heated to the desired temperature limited by the critical non-magnetic temperature of the metal of which the article is composed, and afterwards cooling the said article.

Commercial Items of Interest

CHARLES GRIFFIN & CO., LTD., London, England, announces the publication of a volume by Sir Robert A. Hadfield entitled "The Work and Position of the Metallurgical Chemist" with references to Sheffield and its place in metallurgy. The contents of this book are as follows: Sheffield's Work in the Past and during the War.—The Sheffield Association of Metallurgists and Metallurgical Chemists.—The Chemist.—The Indebtedness of the Metallurgist to Science.—Metallurgical Instruction.—Metallurgy and Poetry.—The Author's Research Work.—Manganese Steel.—Low Hysteresis Steel.—Federation of Engineering Interests.—Electrical Power.—Rapid Cinematography.—American Railroads and their Long Trains.—Ancient Research Workers.—The Royal Society.—Conclusion.

Leeds & Northrup Company have published a booklet on Potentiometer Pyrometers. The booklet points out the functions for which the various types of instruments are intended, and discusses the factors governing the selection of a pyrometer equipment. There are forty-four pages and many illustrations, some of which are in color.

Pittsburgh will be the host of the American Chemical Society at its Annual Fall meeting, from September 4th to September 9th, inclusive. All of the divisional meetings will be held at the Carnegie Institute of Technology, while the general meetings are scheduled at Carnegie Music Hall.

An exceptional program has been outlined for the entire week, with a variety of social events for the Councillors and their wives.

Of outstanding importance in the program will be an address by Thomas Midgley, Jr., of the General Motors Research Corporation on "Chemical Control of Gaseous Detonation with Particular Reference to the Internal Combustion Engine." Mr. Midgley will be assisted by T. A. Boyd. The lecture will include demonstrations of normal combustion and detonation in glass tubes, the suppression of detonation by the addition of certain chemical compounds, and demonstrations with an internal combustion engine motor containing quartz windows and apparatus for measuring radiation. The motor will be operated on detonating and non-detonating fuels. Lantern slides will be shown illustrating the periodic variation of anti-knock value among the 16 elements. Blue-prints of the paper will be issued at the meeting.

"Pittsburgh as a Chemical Manufacturing Center" is the subject of an address to be given by Dr. J. H. James, Head of the Department of Chemical Engineering, and Dr. W. F. Rittman, Head of the Department of Commercial Engineering, of Carnegie Institute of Technology. Dr. James will discuss "Pittsburghs' Raw Materials and Markets for Chemical Products." Dr. Rittman will speak on "Pittsburghs' Transportation and Financial Advantages."

By special arrangements, the Committee of the Pittsburgh Section of the A. C. S. has obtained dormitory privileges for the Councillors at Carnegie Tech during the Meeting. The Men's Dormitories will be opened to house 350. One of the Women's Dormitories has been offered for the use of Councillor's wives.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING. Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U. S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

ENGINEERING or PRODUCTION WORK—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired $200-$250. per month. Address 5-25.

SALESMAN—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

METALLURGIST—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired $4500. per year. Address 5-35.

SUPERVISOR HEAT TREATING—Or assistant. Ten years experience as chemist on iron and steel. One year practical experience on metallurgical inspection directly connected with heat treatment. Have made a study of the subject. No preference as to location. Wages $40.00 per week desired. Answer 5-50.

FURNACE DESIGNER and BUILDER—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

ASSISTANT METALLURGIST—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired $150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

METALLURGIST AND ENGINEER—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

CHEMIST—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

METALLOGRAPHIST desires position in charge of or as assistant in metallographical laboratory. Has had four years experience U. S. Bureau of Standards. Address 8-10

WANTED by a practical man with 22 years' experience with some leading firms of the United States, position as Supervisor or foreman of Heat Treating. Address 8-5

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

HEAT TREATING DEPARTMENT—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary $150.00. Cleveland location preferred. Address 4-10.

EMPLOYMENT SERVICE BUREAU

POSITION WANTED

SUPERINTENDENT OF HEAT TREATING—7 years experience heat treating of carbon. highspeed and other alloy steels. Experience in metallographic testing Understands pyrometry. Techincal education. Best of references. Location desired, Chicago or near vicinity. Address 6-15.

SERVICE MAN—for steel company. Experience in heat treatment of carbon, high speed and alloy steels, also metallographic testing and pyrometry. Technical education. Best references. Address 6-20.

SALES REPRESENTATIVE—At present holding responsible executive position. Desires to become representative of one or more manufacturing lines in excellent territory. Companies especially desiring representative for materials used in heat treating will find it to their advantage to correspond with No. 7-5.

CHEMIST AND METALLURGIST—thoroughly experienced in analysis of ferrous and nonferrous metals. Specialist in alloy steel analysis. Capable of taking charge of chemical and physical laboratory. Best of references. Age 30. Married. Salary commensurate with ability. Answer 7-20.

CHEMICAL AND METALLURGICAL ENGINEER with business education and 3 years practical consulting experience desires a position in laboratory or production departments. Address 7-30.

POSITIONS OPEN

WANTED—Practical Superintendent for tool steel wire and shape drawing department. Reply box 6-5. care American Society for Steel Treating.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specialized in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-15.

WANTED

WANTED—A copy of the book "LIGHT WAVES AND THEIR USES" by A. A. Michelson. State price. Address 8-1

FOR SALE

FOR SALE—Commercial Heat Treating Plant. Established business in good field. Excellent opportunity for young metallurgist to get into business for himself. Answer 7-10.

Leeds & Northrup, Hump Method, Electric Furnace for sale. Used very little. Address6-1.

FOR SALE—A ten-ton Gronwell-Dixon electric furnace with all accessories. This furnace is in excellent condition and is available at a very attractive figure. Address 7-[illegible].

(*Continued from Page* 1067)

The daily service that is being rendered by one of the important branches of the iron and steel business is outlined in a pamphlet entitled "Certified Malleable in Transportation and Industry," issued by the American Malleable Castings Association, Cleveland. It tells the story of certified malleable castings, outlining the means employed by the association in bringing the product of its members to a uniformly high standard and maintaining it at that point. It will be sent to interested persons upon written request to the American Malleable Castings Association, 1900 Euclid Building, Cleveland.

The American Electrochemical Society announces the removal of its national headquarters to Columbia University, New York, after having been located for nearly 20 years at Lehigh University, Bethlehem, Pa. This change is due to the fact that the society's new secretary, Dr. Colin G. Fink, who succeeded the late Dr. Joseph W. Richards, has recently been appointed lecturer in electrochemistry at Columbia, and he will have charge of that division of the university's department of chemical engineering.

By recent action of the society, the adoption of an amendment to the constitution raises the annual dues from $5 to $8 By action of the directors, the organization of a division of organic electrochemistry has been authorized with A W. Burwell as temporary chairman.

G. M. Sherman, formerly representing the Quigley Furnace Specialties Company, has become connected with the Keystone Refractories Company of New York and has been made New England Sales Manager with offices at 818 Hospital Trust Building, Providence, R. I.

Charles H. McKnight, who has held the positions of president and chairman of the Carbon Steel Co., Pittsburgh, resigned from the former office at a

recent meeting of the board of directors. His successor is C. F. Blue, Jr., who has been vice-president and Frank C. Neale, president of Kitanning Iron & Steel Mfg. Co., controlled by the Carbon Steel Co., and a director of the latter, has been made vice-president, in succession to Mr. Blue.

Tate-Jones & Co., Inc., Pittsburgh, furnace engineers, within the past few weeks have closed contracts for 13 Costello patent continuous pair furnaces. Six of these were for the Wheeling Steel Corp., Wheeling, W. Va., six for the Newton Steel Co., Newton Falls, O.; and one for the Superior Sheet Steel Co., Canton, O.

Carnegie Institute of Technology at Pittsburgh has been selected by the United States Naval Academy at Annapolis to give advanced courses in Metallurgy to its graduate officers. The institution is the only school in the country chosen for this work, and its selection is an outstanding tribute to the high standard of its engineering curricula.

Beginning next September, the Naval Academy will send two ordnance officers, graduates of the Academy, for a year's study in advanced metallurgy, at Tech. The officers will be here for the full college year. Their studies will be graduate work in advanced metallurgy with some studies in electricity and physical chemistry. Other groups of graduate officers are assigned each year to various colleges or universities to study along specialized lines.

F. F. McIntosh, Associate Professor in Metallurgy, at Carnegie Tech, will supervise the studies of the Naval Officers. Lieutenants Gilbert C. Hoover and John H. Keefe have been assigned to take the work the next college year.

P. J. Connor, formerly traveling representative for the International Machine Tool Co., Indianapolis, manufacturer of the Libby turret lathe and who recently resigned from the Essley Machinery Co., Chicago, is now engaged with the Haynes Stellite Co., Chicago, in an engineering capacity with headquarters at New York.

The Brown Instrument Co., Philadelphia, has published a catalog in which resistance thermometers are described and illustrated. These operate upon the basis of electrical resistance rather than pressure and they are accurate and rapid. It is claimed that for installation where extreme accuracy is required within a small range of temperature, these thermometers are ideal.

A month's test was recently conducted to determine the utility of a Baily 1-ton nose-tilting type furnace in one of the oldest brass-rolling mills in England. The test charges consisted of cartridge shells and rolling mill scrap, pouring 60-40 brass into round billets, strip molds and condenser plates.

In the test on round billets, 3 to 6 inches in diameter, operating the furnace continuously for 31 heats, 50 hours was consumed in melting and a total of 48,608 pounds of brass was poured. The electrical energy consumed was 306 kilowatt-hours per ton of metal melted.

With a similar charge of cartridge shells and rolling mill scrap pouring 60-40 brass into condenser plates weighing 1700 pounds each 18 heats required

(*Continued on Page 36*)

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, September 1922 No. 12

ON TO DETROIT

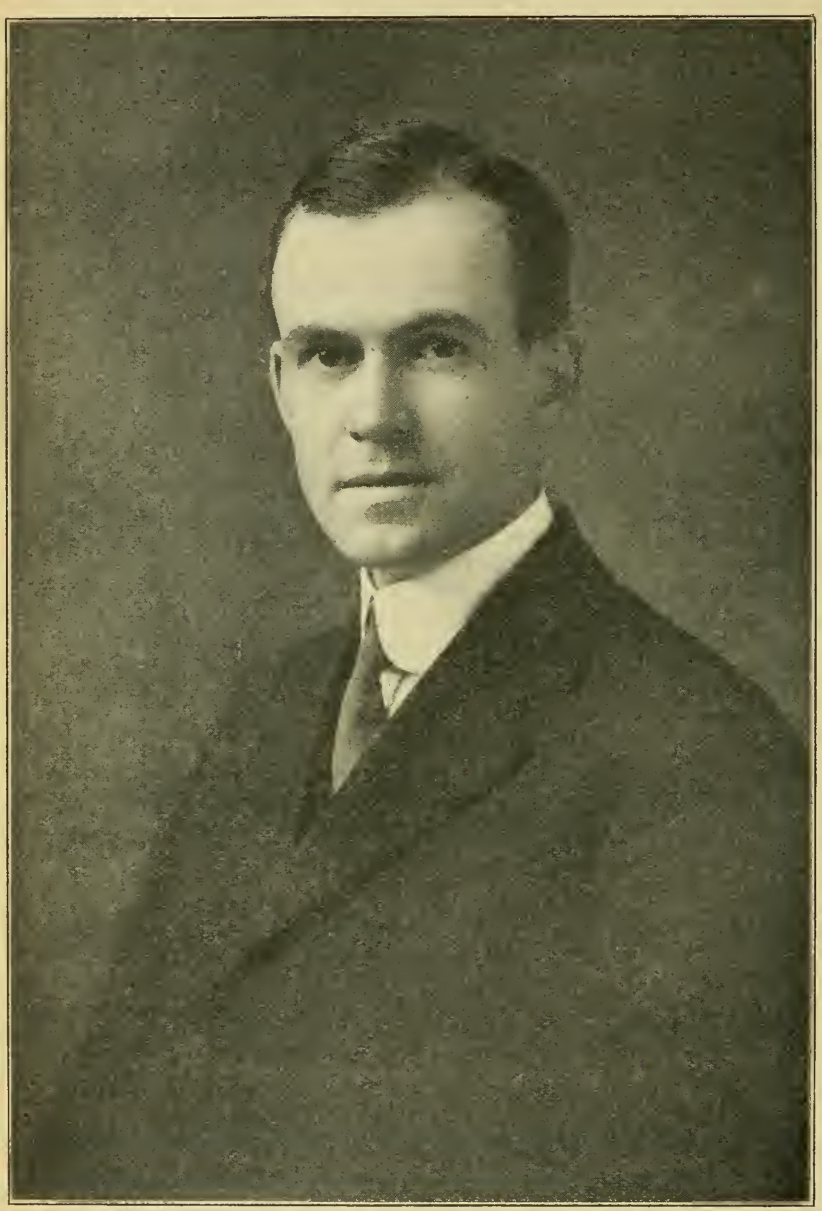
THE annual convention of the American Society for Steel Treating in Detroit the week of October 2nd gives promise of being the best attended of any of the three previous annual meetings. The large percentage of members who attend is remarkable and has occasioned much favorable comment. It is doubtful if any other technical society holding annual meetings has the same percentage of its membership present. There must be and is a reason for this. It is because those who have once attended find the accruing benefits so voluminous that it would be the height of folly to remain away. Not only have the attendants found real meat and satisfaction in the programs presented but the exposition has always made a lasting impression. Its educational value and the wonderful possibilities of observing at first hand the latest and best products, materials and equipment for their use serves as a magnet to draw them back to another convention. Nothing worth while is absent from the exposition because all progressive, wide awake firms are exhibiting. They represent the leaders in their lines just as those in attendance represent the leadership in the intellectual metallurgical thought of the country.

The annual meeting of the best minds at the A. S. S. T. convention is becoming more and more recognized as an essential part of the year's work With the program and exposition increasing both in quality and scope the general benefits will of course be greatly enlarged and the attendance should grow at a greater rate in the future than in the past. Those who have attended previous conventions will be at Detroit. Those who have not owe it to themselves to step out with the leaders.

HARDNESS TESTING AND METALLURGICAL EDUCATION SYMPOSIUMS

WE ARE looking forward with much interest and expectation that the symposium on hardness testing to be held Thursday October 5th in connection with our convention, will accomplish some new and constructive contributions to this very important phase of metal inspection. The nomenclature, the methods employed in testing hardness of metal and the ultimate value of the results obtained in determining the quality or the fitness of a given part to function properly, are matters to be discussed during this session. The term hardness, being simply a relative term, requires defining as there are many misconceptions as to just what the property of hardness signifies in the constitution of a specimen of metal. Then too, the best and most rapid method of determining this property is of equal importance.

The merits of the various methods of testing hardness which are available will probably consume much of the time allowed for discussion. With the aid of the questionnaire which is published in this issue of TRANSACTIONS



FRANK P. GILLIGAN
National President of the American Society for Steel Treating

all those who are interested will have an opportunity to present their views of the various phases of hardness testing prior to this session with the result that a better organized discussion will obtain.

Under the able leadership of Major A. E. Bellis, chairman of this session, we look forward to having an interesting, instructive and constructive contribution to the data already available on the subject of hardness testing.

The symposium on metallurgical education scheduled for Tuesday, October 3rd, promises to be well attended. The purpose of this meeting will be "Not how but what to teach," and should command the interest of not only teachers but men who are in the industrial world in capacities, such that they consume each year in their departments, the product of the various educational institutions. After all is said, it is the observer in the industry who has the opportunity to see the points of weakness of the college graduates and the viewpoints of these men will be valuable in making this meeting a success and will augur well for its institution as a yearly event on our convention program. This surely is a step forward so why not all assist in making its action positive.

This meeting will be under the guidance of Prof. S. L. Goodale, of the University of Pittsburgh. Professor Goodale has had wide experience in the metallurgical instruction of young students and is sure to handle this meeting in a very commendable manner.

SATISFACTION

A LETTER received from a resigning member comments as follows: "I don't need the Society. I know enough about steel treating to hold a job any place."

While we realize that the fourth request for payment of dues may have been sufficient to arouse the recipient's anger and thus cause the sending of the above sentiments, yet we feel that the statement is worthy of notice. In no way disparaging the letter writer's ability, there is no doubt all are familiar with the type of individual to whom further knowledge is useless and who resents any effort to elevate him from the plane in which he lies. In reality he is satisfied with things as they are and dislikes any change in the old order of events.

His principal interest is in the time clock and pay envelope and while he may do his work satisfactorily—that will be all one can say of it for the incentive to do more and better is absent.

It is indeed deplorable and unfortunate not only for the employer but for the employee himself when that individual reaches the viewpoint in life: 'I don't need any help. I know enough."

The number of self-satisfied and self-centered individuals is amazing and we find them not only in the time clock but also in the salary division. Too many are willing to listen to the command, "at ease" or "as you were," when in order to progress and advance they should hear only the command, "Forward March!" Philip Brooks has written a thought with which all will agree: "Sad is the day for any man when he becomes absolutely satisfied with the life he is living, the thoughts that he is thinking and the deeds that he is doing; when there ceases to be forever beating at the doors of his soul a desire to do something larger which he feels and knows he was meant and intended to do."

HENRY MARION HOWE MEDAL

THE Board of Directors of the American Society for Steel Treating with the approval of Mrs. Howe has set aside a fund from the treasury of the Society to be known as the Henry Marion Howe Fund, the proceeds from which will apply on an annual medal to be known as the Henry Marion Howe Medal.

The medal will be of gold and will be presented to the author of the paper considered of highest merit on any subject within the field covered by the Society.

The establishment of this medal is a tribute to the exceptional contributions to the science of metallurgy made by the late Dr. Howe. In this way the Society will recall annually the achievements of its distinguished Honorary Member.

The rules governing the award of the medal will be announced during the International Steel Exposition and Convention of the Society to be held at Detroit, October 2-7.

THE EXPOSITION

FINAL arrangements are being made for the fourth International Steel Exposition and Conventions of the American Society for Steel Treating and the American Drop Forging Institute to be held in the General Motors Building, Detroit, Michigan, October 2-7.

The Exposition will be the largest ever held, as 99 per cent of the floor space has been sold and many exhibitors who desired to be present will be unable to be accommodated. There will be quite a number of exhibitors who have not been present at previous shows due to the fact that the Drop Forging Institute is holding its Annual Convention simultaneously and in the same building with the American Society for Steel Treating, and many members of the Drop Forging Supply Association are accepting the opportunity to exhibit.

The General Motors Building is especially adapted for exhibition purposes. In the large exhibition hall, there are 30,000 square feet, while the two wings on the same floor leading to the exhibition hall has 20,000 additional square feet of display space. All but a few booths have been sold. Arrangements have been made so that in one section of the hall gas furnaces will be in operation, while electrical furnaces and other equipment requiring power will be displayed throughout the hall. Practically all of the exhibits will be in operation.

At the three previous expositions held at Chicago, Philadelphia and Indianapolis, the attendance has been in excess of 10,000 and it is expected that because of the great interest in Detroit as a heat treating center, as well as a market for steel, the attendance will be in excess of 15,000.

The railroads have granted fare and one-half for the round trip to Detroit on account of the Conventions. In order to be able to take advantage of this reduced fare which applies not only to the holder of the certificate but to the members of his family as well, it is necessary that one should have an identification certificate. These may be obtained by addressing the National Secretary of the American Society for Steel Treating, Mr. W. H. Eisenman, 4600 Prospect Avenue, Cleveland, Ohio.

Certificates will be mailed to all members about Sept. 15th.

Reduced fare tickets may be purchased September 28, return limit being October 13th.

A complete list of exhibitors and floor plan is given on other pages.

PLANT VISITATION

Mr. W. B. Hurley, Chairman of the Plant Visitation Committee, is making arrangements for the visitation of the following plants:

Ford Motor Company (Highland Park Plant), Ford Motor Company (River Ridge Plant), Cadillac Motor Company, Central Forge & Gear Company, Lincoln Motor Car Company, Detroit Steel Products Company, Detroit Twist Drill Company, Hudson Motor Car Company.

There will be two sessions of plant visitors each day, both of them starting from the General Motors Building, the morning session at 10:00, and the afternoon session at 2:00. Plant visitation may be arranged on Tuesday, Wednesday, Thursday or Friday of Convention week. By this excellent and convenient arrangement, it will be possible for visitors to select the plant they wish to visit as well as arrange the time so that they will not miss any of the sessions in which they are particularly interested.

MEMORIAL TABLET

Probably one of the most interesting events to occur during the International Steel Exposition and Convention of the American Society for Steel Treating at Detroit, October 2nd to 7th will be the unveiling of a bronze tablet dedicated to the memory of those pioneers of the steel industry who in 1864 at Wyandotte, Michigan, erected the first Bessemer Steel Converter used commercially for the manufacture of Bessemer Steel in America.

This tablet is to be erected by the Detroit Chapter of the American Society for Steel Treating through its Executive Committee and Messrs. Atkinson, Hamilton and McCloud, acting as a special committee.

The site of the Wyandotte Iron Works where Kelly's first tilting Bessemer steel converter was erected is the present location of the Wyandotte Public Library and permission has been secured from the Library Board for the placing of this tablet on the front of the building.

The tablet will be 24 x 36 inches and at the head of it will be a bas-relief of the original converter.

The unveiling exercises will probably be held on Thursday afternoon, October 5, and the Governor of Michigan has indicated his intentions of being present, and other speakers of prominence are being invited and many have signified their intention to be present.

It is interesting to note that the erection of this tablet is the first public recognition of the achievements of William Kelly who made his first Bessemer steel in 1847 and finally patented his process in 1856 although it was eight years later before the Wyandotte Iron Works produced the first Bessemer steel for commercial purposes.

Shortly before Mr. Kelly's death he said to his children, "the day will come when someone will do me justice." It remained for the Detroit Chapter of the American Society for Steel Treating to commemorate the achievement of the early pioneers in the development of the process that caused the United States to become the supreme steel making nation in the world.

SYMPOSIUM ON METALLURGICAL EDUCATION

Owing to the requests from many members of the American Society for Steel Treating in the teaching profession that an opportunity should be given them to have a conference with metallurgical engineers who are engaged in commercial industries so that the universities and colleges might better prepare their students for the greatest usefulness, a symposium on metallurgical

education has been placed on the program of the convention of the American Society for Steel Treating at Detroit and will be held at 4:00 p. m., on Tuesday, Oct. 3. At this symposium it is not proposed to discuss "how to teach" metallurgy, but "what" metallurgical subjects should receive the greatest *emphasis*.

Professor S. L. Goodale, University of Pittsburgh, will be Chairman of the session, while others contributing to the symposium will be Howard J. Stagg, Assistant Manager of Halcomb Steel Company; H. B. Knowlton, Central Continuation School, Milwaukee; Professor John Keller, Iron and Steel Extension Department of Purdue University; Professor H. M. Boylston, Professor of Metallurgy, Case School of Applied Science; Dr. N. B. Hoffman, Metallurgist, Colonial Steel Company; Mr. McCleary, Metallurgist, Dodge Motor Car Company; Dr. John A. Mathews, President, Crucible Steel Company of America; Professor O. A. Knight, State College, Pa.; Professor Frederick Crabtree, Carnegie Institute of Technology; and Dr. C. M. Johnson, Crucible Steel Company of America; W. C. Peterson, Manager, Alloy Steel Division, Atlas Steel Corp., and many others.

This symposium on "Not How" but "What to Teach" is the first symposium on metallurgical education ever held in the United States and is expected to be productive of very desirable results and to be a regular feature of the future conventions of the American Society for Steel Treating.

SYMPOSIUM ON HARDNESS TESTING

The Hardness Committee of the National Research Council will hold an important symposium during the International Steel Exposition at Detroit, October 2nd to 7th.

This committee has already done a great amount of very valuable work on the subject of hardness testing and this meeting of the committee will undoubtedly have very important results.

The symposium will be in charge of Major A. E. Bellis, formerly Metallurgist, U. S. Armory, Springfield, and at present President, Bellis Heat Treating Company, New Haven.

The program will be as follows:

"Object of Committees, Investigation and Questionnaire," by Major A. E. Bellis, Chairman of Hardness Testing Committee.

"Significance of Hardness Tests," by Dr. H. P. Hollnagel, General Electric Company.

"Hardness and Its Relation to Magnetic Properties," by Professor R. S. Williams, Oberlin College.

"Discussion of Methods of Hardness Testing."

ANNUAL BANQUET

The Annual Banquet of the American Society for Steel Treating and the American Drop Forging Institute will be held jointly in the ball room of the Statler Hotel during the International Steel Exposition and Conventions of the two societies at Detroit, October 2nd to 7th.

The date of the banquet is Thursday evening, October 5. The doors will be open at 6:30 and banquet will be served at 7:00.

Mr. C. F. Kettering, President of the Dayton Engineering Laboratories Company and a member of the American Society for Steel Treating since its organization, will serve as toastmaster. President Burton of the University of Michigan, one of the best dinner speakers in the country, will address the

banqueters. There will be other speakers of national prominence including the Governor of Michigan and some chief executives of the largest steel companies in the country.

The number of banqueters will be limited to 1000.

ENTERTAINMENT

Plans have been made by the Detroit Chapter for the entertainment of members and guests of the American Society for Steel Treating and the American Drop Forging Institute when they hold their convention in Detroit during the International Steel Exposition, General Motors Building, October 2nd to 7th.

Monday evening, October 2nd, has been left open in order that the visitors may have the opportunity to thoroughly study the exhibits which will be the most extensive ever shown.

On Tuesday evening, October 3rd, beginning at 9:30, Mr. Frank G. Davis, Chairman of the Entertainment Committee, with the assistance of the Detroit Chapter will give a smoker in the large Auditorium of the General Motors Building.

On Wednesday evening, October 4th, beginning at 9:00 in the main auditorium of the General Motors Building, the Detroit Chapter will hold a Carnival, Frolic and Dance for the members of the Society and their guests. All of the entertainment features of a Carnival as well as the necessary adjuncts for a joyous frolic will be on hand. Not the least in importance at the carnival and frolic will be the two high grade orchestras providing music for the dancers.

On Thursday evening, October 5th, will be the Annual Banquet at the Statler Hotel at which speakers of national prominence will be present and at which, because of the size of the banquet hall, only 1000 will be able to attend.

LADIES' ENTERTAINMENT

The entertainment of the ladies has always been one of the most successful events of the conventions of the American Society for Steel Treating.

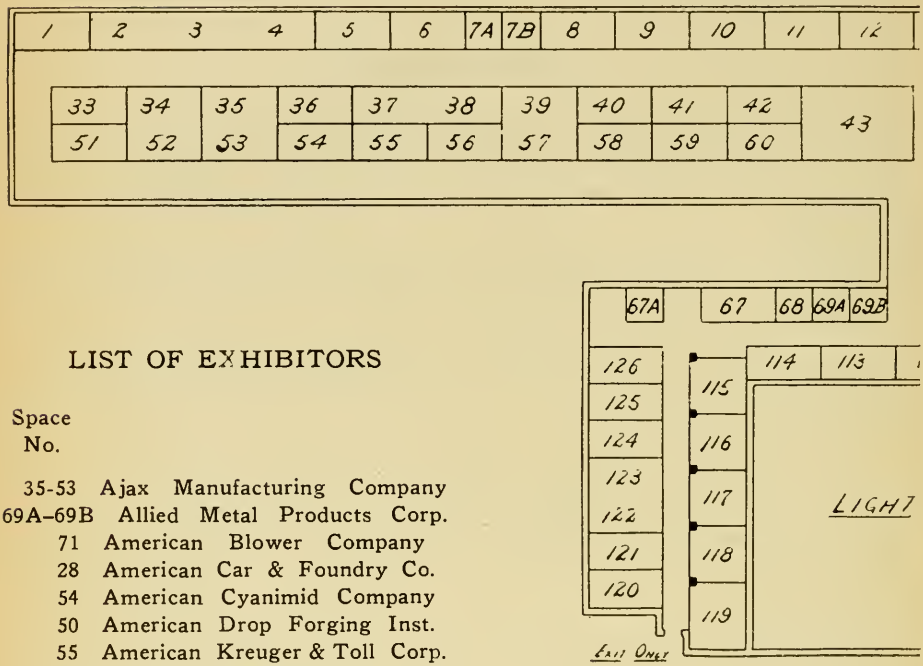
There have always been in the neighborhood of 100 visiting ladies present and inasmuch as the ladies of the American Drop Forging Institute are also to be entertained simultaneously with those of the American Society for Steel Treating, it is expected that at least 200 will be at the Detroit party during the week of October 2nd.

While no definite program is at present available, nevertheless, Mr. W. J. Learmouth, Studebaker Corporation, Chairman of the Ladies Entertainment Committee, has completed arrangements for a continual round of entertainment, sight seeing and auto trips for the guests.

The ladies will of course attend the Carnival, Frolic and Dance to be held at the General Motors Building on Wednesday, October 4, as well as attend the banquet at the Statler on Thursday evening. It has always been the motto of the American Society for Steel Treating for their members to bring their families and lady friends along and check them with the Entertainment Committee, and the same favorably received policy will be in vogue during the Detroit Convention.

(*Continued on page* 1080)

FLOOR PLAN AND LIST OF EXHIBITORS GENERAL MOTORS BUILDING

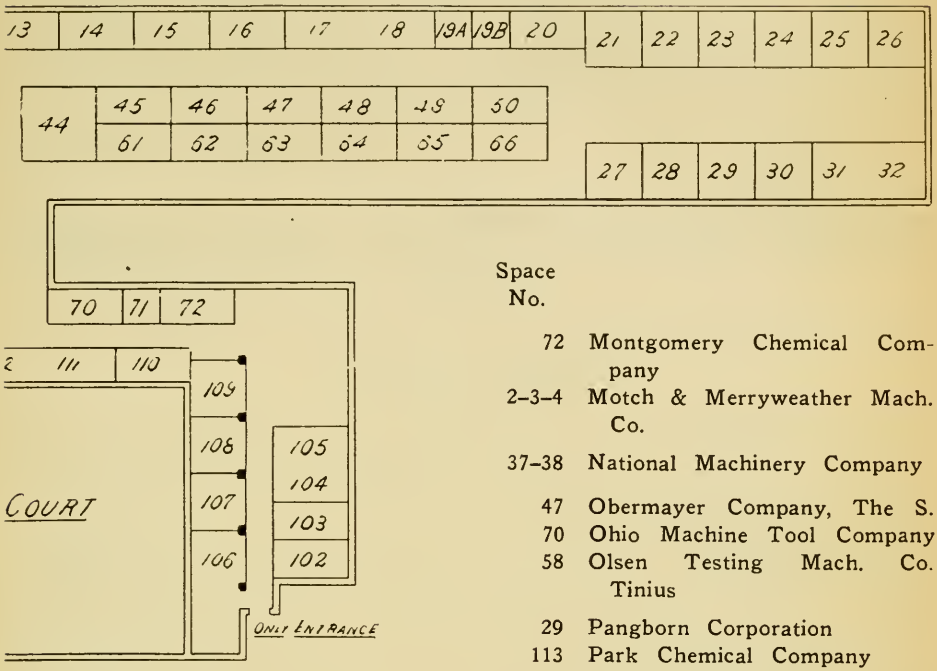


LIST OF EXHIBITORS

Space No.	
35-53	Ajax Manufacturing Company
69A–69B	Allied Metal Products Corp.
71	American Blower Company
28	American Car & Foundry Co.
54	American Cyanimid Company
50	American Drop Forging Inst.
55	American Kreuger & Toll Corp.
67A	American Refractories Co.
114	American Twist Drill Company
30	Armstrong-Blum Mfg. Co.
42	Armstrong Cork & Insul. Co
41	Atlas Steel Corporation
10	Bausch & Lomb Optical Co.
21	Bellevue Industrial Furn. Co.
106	Bethlehem Steel Company
125	Blaich Company, The A. O.
12	Bristol Company
61	Brown Instrument Company
117	Bureau of Standards
66	Calorizing Co. of Pittsburgh
23	Carborundum Company
14	Case Hardening Service Co.
48	Celite Products Company
111–112	Central Steel Company
25	Chicago Flexible Shaft Co.
43	Climax Molybdenum Company
16	Colonial Steel Company
68	Combustion Utilities Corp.
34	Crucible Steel Co. of America
108	Dearborn Chemical Company

Space No.	
1	Driver-Harris Company
27	Electric Furnace Company
26	Electro-Alloys Company
8	Engelhard, Inc. Chas.
43	Finkl & Sons, A.
104–105	Firth-Sterling Steel Company
7a	Ford Company, The J. B.
64	Forging & Heat Treating
9	Ganschow Company, Wm.
7B	Goddard & Goddard Co. Inc.
44	General Alloys Company
31-32	General Electric Company
13	Hagan Company, The Geo. J.
52	Halcomb Steel Company
118	Hauck Manufacturing Company
56	Haynes-Stellite Company

INTERNATIONAL STEEL EXPOSITION
DETROIT, MICHIGAN



Space No.	
11	Heppenstall Forge & Knife Co.
49	Holcroft & Company
63	Hoskins Manufacturing Co.
33	Houghton & Company, E. F.
115	International Nickel Co.
40	Interstate Iron & Steel Co.
15	Iron Age
5	Keller Mechanical Engrav. Co.
116	Keystone Refractories
67	King Refractories Co.
19a	Kleist & Company, Chas.
39–57	Leeds & Northrup Company
45	Leitz, Inc. E.
193	Machinery
6	Midvale Steel & Ordnance Co.
55	Midwest Steel & Supply Co.

Space No.	
72	Montgomery Chemical Company
2–3–4	Motch & Merryweather Mach. Co.
37–38	National Machinery Company
47	Obermayer Company, The S.
70	Ohio Machine Tool Company
58	Olsen Testing Mach. Co. Tinius
29	Pangborn Corporation
113	Park Chemical Company
65	Penn Seaboard Steel Corp.
109	Quigley Furnace Specialties Co.
62	Rockwell Company, The W. S.
36	Rodman Chemical Company
126	Shore Instrument & Mfg. Co.
51	Simonds Manufacturing Co.
20	Spencer-Turbine Company
124	Standard Alloys Company
24	Standard Fuel & Engr. Co.
102	Standard Steel & Bearings, Inc.
22	Surface Combustion Company
110	Taylor Instrument Company
60	Taylor Company, The N. & G.
122–123	United Alloy Steel Company
107	Vanadium Alloys Steel Company
103	Vanadium Corporation of Am.
17–18	Westinghouse Elec. & Mfg. Co.
46	Wilson-Maeulen Company
59	Witherow Steel Company

(*Continued from page* 1077)

DROP FORGE SUPPLY ASSOCIATION

Mr. H. N. Taylor, President of the N. & G. Taylor Company and President for the past eight years of the Drop Forge Supply Association, has made arrangements for the holding of a meeting of the members of the association during the International Steel Exposition and Conventions of the American Society for Steel Treating and the American Drop Forging Institute in Detroit.

The meeting will be held at 12:30 on Tuesday, October 3, in the General Motors Building.

PROGRAM — ANNUAL CONVENTION — AMERICAN SOCIETY FOR STEEL TREATING —GENERAL MOTORS BUILDING— DETROIT

The following program is subject to change.

MONDAY, OCTOBER 2

Morning Session

11:00 A. M. Exposition open until 10:00 P. M.
11:00 A. M. Registration.
All technical sessions held in General Motors Building.

Afternoon Session

2:00 P.M. Plant Visitation.
L. A. Danse, Chairman.
Address of Welcome.....L. A. Danse
Welcome to Detroit.....Mayor Cousins
Response .....Pres. F. P. Gilligan
Report of Tellers of Election .....C. G. Shontz
Introduction New Officers.
Report of National Secretary .....W. H. Eisenman
Report of Treasurer.....J. V. Emmons
Report of National Committees.
President's Address .....F. P. Gilligan

TUESDAY, OCTOBER 3

Morning Session

10:00 A. M. Exposition open until 10:00 P. M.
10:00 A. M. Plant Visitation.
10:00 A. M. Carburizing Session.
Carburizing and Decarburizing in Case Hardening.....H. B. Knowlton
Case Handening.....A. H. d'Arcambal
Irregularities in Case Hardened Work Caused by Improperly Made Steel .....E. W. Ehn
Some Features of Industrial Heat Treating Electrically .....C. L. Ipsen

Afternoon Session

2:00 P. M. Plant Visitation.
2:00 P. M. Delegate Session.
Chairman, T. D. Lynch.
Vice Chairman, A. W. F. Greene.
2:00 P. M. The Mining and Metallurgy of Nickel—Illustrated.....A. J. Wadhams
4:00 P. M. Symposium on Metallurgical Education.
"Not How but What to Teach".
Prof. S. L. Goodale, University of Pittsburgh, Chairman.
4:00 P. M. Practical Round Table Discussion on Heat Treating.
H. J. Lawson, Chairman.
9:30 P. M. Smoker and Entertainment.
Auditorium—General Motors Building.

WEDNESDAY, OCTOBER 4

Morning Session

10:00 A. M. Exposition open until 10:00 P. M.

10:00 A. M. Plant Visitation.
10:00 A. M. General Heat Treating Problems.
Heat Treating in Lead ..... R. B. Schenck
Furnace Atmospheres and Their Relation to Formation of Scale.
..... G. C. McCormick
Paper ..... J. H. Nelson
Thermal Transformation of Some Chrome Vandium Steels..... J. S. Vanick
Heat Treating of Auto Springs..... A. E. Fuller

Afternoon Session

2:00 P. M. Plant Visitation.
2:00 P. M. Drop Forge Institute Session.

Papers

The papers during this session will be presented by the American Drop Forging Institute and will be of great interest and practical value to the executives of all industrial organizations.
4.00 P. M. Practical Round Table Discussion on Heat Treating.
Chairman, John Halbing.
9:00 P. M. Carnival, Frolic and Dance.
Auditorium—General Motors Building.

THURSDAY, OCTOBER 5

Morning Session

10:00 A. M. Exposition open until 5:30 P. M.
10:00 A. M. Plant Visitation
10:00 A.M. Tool Steel Session.
The Uses and Abuses of Tool Steels from the Standpoint of the Producer and Consumer ..... W. P. Woodside
Paper ..... A. E. White
Effects of Structure upon Machining of Tool Steel..... J. V. Emmons
A Metallographic Study of Hollow Drill Steel..... N. B. Hoffman

Afternoon Session

2:00 P.M. Plant Visitation.
2:00 P. M.
Some Failures in Aircraft Plane and Engine Parts..... J. B. Johnson
Lathe Breakdown Tests of Some Modern High Speed Tool Steels.
..... H. J. French and Jerome Strauss
Paper ..... F. M. Nair
Deterioration of Steel and Wrought Iron in Hot Gaseous Ammonia. J. S. Vanick
4:00 P. M. Practical Round Table Discussion on Heat Treating Problems.
Robt. Vincent, Chairman.
7:00 P. M. Annual Banquet—American Society for Steel Treating and American Drop Forging Institute.
Ball Room—Statler Hotel.
Doors open 6:30 P. M.

FRIDAY, OCTOBER 6

Morning Session

10:00 A. M. Exposition open until 10:00 P. M.
10:00 A. M. Plant Visitation.
10:00 A. M.
Heat Treatment and Properties of Duralumin..... H. C. Kneer
10:45 A. M. Meeting of Standards Committee of American Society for Steel Treating.
T. D. Lynch, Chairman
10:45 A. M. Modern Methods in the Manufacture of Steel.
Moving Pictures.

Afternoon Session

2:00 P.M. Plant Visitation.
2:00 P. M. Research Session.
A. E. White, Chairman.
Governmental Research ..... W. M. Corse
Research on Activities of Technical Societies..... A. D. Flinn
The Research Laboratory..... F. O. Clements
The Executive and Research..... John A. Mathews

LIST OF EXHIBITORS AND WHAT THEY WILL EXHIBIT AT INTERNATIONAL STEEL EXPOSITION, GENERAL MOTORS BUILDING, DETROIT, OCTOBER 2-7

Ajax Manufacturing Company, Cleveland. Spaces 35-53, will exhibit:
Working Model Twin Geared Upsetting Forging Machine, length overall about 30 inches, made principally from aluminum.
Working Model, motor-driven direct gear connected Board Drop Hammer about 30 inches high, made principally from aluminum.
Display of interesting sample forgings, all made by Ajax Machine methods.
In charge of booth: J. R. Blakeslee, President; W. W. Criley, R. A. Bannerman, H. D. Heman, all from Cleveland office. J. A. Murray, Manager, New York office; A. L. Guilford, Manager, Chicago office.

Allied Metal Products Corporation, Detroit. Space 69, will exhibit:
Nickel Alloys. Heat resisting—non-corrosive, in sheets, bars and castings and finished product.
In charge of booth: V. Hybinette, W. J. Moore.

American Blower Company, Detroit, Mich. Space 71, will exhibit:
Man Cooling Fan—operates as a very large desk fan directing a cooling breeze over workmen employed before furnaces or other hot machines.
Pressure Blower—for furnishing blast for furnaces.
Utility Blower—for blowing scale from forging dies.
Domestic Kitchen Ventilating Unit—something new to take the odors, steam and fumes from the kitchen, an article of general interest.
In charge of booth: G. C. Polk, Manager, Standard Apparatus Division; J. B. Dill, Manager, Detroit sales office; O. F. Polk, Manager, Standard Apparatus Division; W. A. Rane, Chief Engineer.

American Car & Foundry Company, New York City. Space 28, will exhibit:
One No. 3 Three Electrode Berwick Electric Rivet Heater for heating rivets or short pieces of steel electrically.
One No. 3 One Electrode Type E Berwick Two Path End Rod or Forging Heater for heating one end of a rod of any diameter from ¼-inch to 1-inch, giving any desired length of heat from 1-inch to 8 inches, or longer if desired.
One No. 3 Four Foot Berwick Electric Rod Heater, for heating any diameter rod up to 1 inch, for hand feet rivet and bolt machine and for long heats in forging operations.
In charge of booth: J. M. Hayes, A. G. Wood, A. F. Frost, F. C. Cheston.

American Cyanamid Company, New York City. Space 54, will exhibit:
Cyanide Products for Heat Treating Steel.
In charge of booth: E. J. Pranke.

American Drop Forging Institute, Cleveland. Space 50, will exhibit:
Typical Drop Forgings supplied by executive members of Institute.
In charge of booth: R. E. Waldron, Dominion Forge & Stamping Co., Walkerville, Ontario, Canada.

American Kreuger & Toll Corporation, New York City. Space 55, will exhibit:
Air Filters; transmission steel sections, timber joint plate.
Nitrol—a new hardening process.
In charge of booth: Dr. F. Rohde.

American Twist Drill & Tool Company, Detroit. Space 114, will exhibit:
High Speed Drills and Cutting Tools.
In charge of booth: L. C. Gonham, C. G. Munn, F. E. Henderson.

Armstrong-Blum Mfg. Company, Chicago. Space 30, will exhibit:
"Marvel" Automotive High Speed Hack Saw Machine.
"Marvel" Metal Band Saw.
"Marvel" Punch, Shear and Bender.
In charge of booth: H. J. Blum, Secretary, Chicago; G. J. Blum, Vice President, Chicago.

Armstrong Cork & Insulation Company, Pittsburgh. Space 42, will exhibit:

Nonpareil Insulating Brick for insulation of furnaces, ovens, boiler settings, kilns, retorts, etc.
Nonpareil High Pressure Covering, blocks and cement for insulation of steam lines, boilers and other high temperature equipment.
Nonpareil Cork Covering for insulation of refrigerated drinking water, brine and ammonia lines, coolers, tanks, etc.
Nonpareil Corkboard Insulation for insulaton of cold storage and constant temperature rooms, tanks, etc.
Linotile and Armstrong's Cork Tile for floors.
In charge of booth: S. L. Barnes, Advertising Department; W. C. Rasch and E. D. Summers, of Detroit office.

Atlas Steel Corporation, Dunkirk and Charleroi, Pa. Space 41, will exhibit:

Full line of tool and high speed steels; also samples and fractures of same in various metallurgical conditions.
Full line of special steels, such as magnet, valve, non-corrosive and ball-bearing steels.
Description of alloy steels manufactured and their applications.
In charge of booth: W. C. Peterson, M. Grossmann, Frank Lounsbury, Wm. H. Wills.

Bausch & Lomb Optical Company, Rochester, N. Y. Space 10, will exhibit:

Complete line of metallurgical microscopes and metallographic equipment, ranging from simplest types, suitable for general foundry use, to most complete equipments for research laboratory work.
New Contour Measuring Projector, by means of which contour of screw threads, gear cutting tools and small machine parts may be accurately and rapidly checked. This equipment should be of much interest to the Steel Treater, as it will be the means of definitely settling the question of distortion, due to heat treatment.
These equipments will be in actual operation, and our representatives will welcome the opportunity of conferring with those interested in installation of equipment or those already having equipment upon which additional information may be desired.
In charge of booth: W. L. Patterson, I. L. Nixon.

Bellevue Industrial Furnace Company, Detroit, Mich. Space 21, will exhibit:

One High Speed Furnace with casing cut away to show interior construction.
A duplicate of above furnace under actual operation.
Pyrometer equipment in connection with above to be supplied by Brown Instrument Company.
In charge of booth: P. P. Barker, Walter Hinz, L. J. Raymo, C. Voelker, Erich Hinz.

Bethlehem Steel Company, Bethlehem, Pa. Space 106, will exhibit:

Castings made with Mayari Pig Iron—A pig iron made from ores containing nickel and chromium naturally and used for automobile cylinders, pistons and other special iron castings.
Bethlehem Rolled Steel Wheels.
In charge of booth: T. J. Fitzgibbons, Sales Agent—Drop Forgings. W. C. Cutler, Sales Agent—Bars and Billets. Robt. MacDonald—Foundry Specialist. P. Kruelen—Foundry Specialist. F. A. Wallen, Sales Agent—Bethlehem Rolled Steel Wheels. W. R. Shimer, Sales Metallurgist.

Alfred O. Blaich Company, Detroit, Mich. Space 125, will exhibit:

Carbonizing Materials.
"Quick Case"—for cyaniding purposes.
"Quick Heat"—for heat treating purposes.
INSULITE—for selective hardening.
Leadcoat—for covering lead bath.
Specimens treated with Blaich Products.
In charge of booth: Frederick Pugh, 555 Beaufait Ave., Detroit; J. A. Howland, 555 Beaufait Ave., Detroit; S. W. Baldwin, 555 Beaufait Ave., Detroit.

Bristol Company, Waterbury, Conn. Space 12, will exhibit:

Bristol's Recording Indicating Electric Pyrometers, Controllers, etc.
In charge of booth: H. L. Griggs.

Brown Instrument Company, Philadelphia. Space 61, will exhibit:

Low and High Temperature Automatic Control.
Indicating and Recording Pyrometers, Recording Thermometers, Pressure Gauges, etc.
In charge of booth: Geo. W. Keller.

British American Nickel Corporated, Ltd. Space 69, will exhibit:

Nickel in ingot.
Cathode and shot form.
In charge of booth: L. J. Buck.

Bureau of Standards, Washington, D. C. Space 117, will exhibit:

General equipment available for research and testing of metals at the Bureau of Standards will be shown by photographs and transparencies and copies of publications considered of interest to the members of the two societies will be available for examination.

A recording chronograph for direct plotting of inverse rate heating and cooling curves, which was recently constructed at the Bureau, will be in operation.

Production of pure metals such as iron and preparation of gas free alloys, together with melting of different industrial ferrous and non-ferrous metals by various methods, will likewise be illustrated.

In connection with this work, methods developed for determination of gases in metals will be shown. Such investigations, which have been pursued intensively for several years at the Bureau of Standards, are fundamental and their perfection must necessarily be achieved before the effects of various gases contained in alloys, such as steels, manufactured by various processes may be determined.

Hot and cold working of metals, their heat treatment and testing including some applications of the 2,300,000-lb. Emery testing machine will be shown. There will also be included the results of recent studies of the properties of ferrous and non-ferrous metals at high temperatures and a model car wheel, showing a method of study of the distribution of stresses under conditions approximating those of service.

A set of gages finished by the Hoke method and typical standard samples prepared by the Bureau will be at hand.

The material available will illustrate the field of co-operation of the Bureau with the metal industries.

In charge of booth: G. K. Burgess, H. J. French, J. S. Vanick, T. G. Digges, Miss D. E. Kingsbury.

Calorizing Company of Pittsburgh. Space 66, will exhibit:

Calorized Recuperator Tubes; Calorized Pyrometer Protection Tubes; Calorized Annealing and Carburizing Tubes and Calorized Burners.

Calite Roller for continuous furnaces; Calite furnace skids; Calite pots and boxes.

Photographs of installations of Calorizing and Calite.

In charge of booth: B. L. Jarrett, President; A. V. Farr, Vice President, and Sales Manager; E. L. Malone, F. D. Rice.

Carborundum Company, Niagara Falls. Space 23, will exhibit:

Refractory Materials.
Abrasive Materials.
In charge of booth: W. W. Sanderson, C. E. Hawke.

Case Hardening Service Company, Cleveland, Ohio. Space 14, will exhibit:

Case Hardening Compound and Hardening Room Supplies.
Samples of:
Bohnite for Pack Hardening.
Caseite for Cyanide Hardening.

Samples of work produced by representative manufacturers using our materials.
In charge of booth: E. J. Gossett, C. E. Lovejoy, W. C. Bell, C. E. Pullum, J. L. Stroman, Wm. H. Bell

Celite Products Company, Chicago. Space 48, will exhibit:
Small electric furnace, one side of which is constructed of ordinary fire brick and other of Sil-O-Cel Insulating Brick. Thermometer attached to the exterior of each side to show how easily heat penetrated fire brick and resistance to heat flow of Sil-O-Cel Insulation.
Complete display of all Sil-O-Cel Insulating products as well as Filter-Cel for filtration and Celite Mineral Filler.
In charge of booth: C. L. Burnham, Chicago; A. B. Rogers, Detroit.

Central Steel Company, Massillon, Ohio. Spaces 111-112, will exhibit:
Alloy Steels—Various finished products made from alloy steels.
Steel Sheets—High-finish automobile sheets.
Strip Steel—Hot Rolled Alloy Steel and Hot Rolled Carbon Steel.
Physical charts, microphotographs.
In charge of booth: F. J. Griffiths, Vice President and General Manager; J. M. Schlendorf, Director of Sales; Gilbert Canterbury, Manager Sales Promotion; Earl Smith, Chief Metallurgical Engineer; C. P. Richter, Metallurgical Engineer; Arthur Schaeffer, Manager Detroit Sales Office.

Chicago Flexible Shaft Co., Chicago. Space No. 25, will exhibit:
Furnaces in operation, controlled by the Selas System.
In charge of booth: Peter Blackwood.

Climax Molybdenum Company, New York City. Space 43, will exhibit:
Products made from Molybdenum Steel.
In charge of booth: John D. Cutter.

Colonial Steel Company, Pittsburgh, Pa. Space 16, will exhibit:
Material used in the Manufacturing of Colonial Tool Steels.
In charge of booth: N. B. Hoffman, Metallurgist; J. Trautman, Jr., Assistant General Sales Manager; G. W. Hampshire, Manager Detroit Branch; C. O. Sternagle, Manager Chicago Branch; F. L. Stevenson, Manager Cleveland Branch; Colin McInnis, Special Sales Agent; Chas. Kopenhoefer, Special Sales Agent; Jesse M. Smith, Special Sales Agent; J. E. Barry, Special Sales Agent.

Combustion Utilities Corporation, New York City. Space 68, will exhibit:
Lead and Oil Tempering Bath.
Muffle Furnace Rivet Forge.
Recuperator Sections.
Drawings for Recuperative and Regenerative Furnaces.
Wooden Models of Recuperative Forge Furnace and Recuperative Heat Treating Furnace.
In charge of booth: G. L. Ballard, 915 Park Avenue, Beloit, Wisconsin; P. J. Nutting, 327 S. Erie Street, Toledo, Ohio; H. M. Henry, 327 S. Erie Street, Toledo, Ohio.

Crucible Steel Co. of America, New York City. Space 34, will exhibit:
High Speed, Carbon and Alloy Tool Steels.
Hot Rolled, Cold Rolled and Cold Drawn Shapes.
Non-Changeable, Non-Corrosive, Acid and Rust Resisting Steels.
Alloy Machinery Steels of all varieties and for every purpose.
In charge of booth: Dr. John A. Mathews, President; R. Michener, General Sales Agent; C. M. Johnson, Director Research Department; A. L. Ralston, Manager Detroit Branch; J. W. Taylor, F. J. White and other representatives of Sales, Operating and Service departments.

Dearborn Chemical Company, Chicago. Space 108, will exhibit:
No-Ox-Id, The Original Chemical Compound Rust Preventive in various consistencies and methods of application.
Quenching Oils.
Cutting Oils.
Cleaners, Powdered and Liquid, known as Klean Kleen and Dearboline.
In charge of booth: E. M. Converse, Director Department of Specialties, Dear-

born Chemical Company, Chicago, Illinois; O. L. Fleugel, Detroit; C. I. Loudenback, Detroit; E. H. Ruhlman, Cleveland; C. A. Remsen, Washington; T. H. Platt, New York.

Driver-Harris Company, Harrison, N. J. Space 1, will exhibit:

Nichrome Castings.

In charge of booth: W. E. Blythe, Driver-Harris Company, Detroit, Michigan; L. Edwards, Canadian Driver-Harris Co., Ltd., Walkerville, Ontario, Canada; H. O. Hartdegen, Driver-Harris Company, Detroit, Mich.; H. D. McKinney, Driver-Harris Company, Chicago, Ill.; G. A. Rickert, Driver-Harris Company, Harrison, N. J.

Electric Furnace Company, Salem, Ohio. Space 27, will exhibit:

Typical products which are being produced in electric furnaces for heating, heat-treating, annealing and enameling in this country.

Exhibit will show wide range of application of electric heat for these purposes.

Products will range from anchor chain, draw bar knuckles and locomotive axles, down to bolts, ball races and small steel parts.

Also model furnace units to show latest designs in electric furnace for metallurgical problems.

In charge of booth: T. F. Baily, Vice President; R. F. Bensinger, Sales Manager; F. J. Peterson, Detroit Representative; R. F. Fletcher, Advertising Manager; M. T. Ellis, Salesman.

Electro-Alloys Company, Elyria, Ohio. Space 26, will exhibit:

Thermalloy castings showing products and various uses.

Difficult castings.

In charge of booth: Heman Ely, Jr.

Chas. Engelhard, Inc., New York City. Space 8, will exhibit:

Complete line of temperature measuring instruments in operation, including both indicating and recording Le Chatelier Pyrometers and recording electric resistance thermometers.

Automatic control apparatus applicable to electric, gas or oil fired furnaces will be shown and controls on electric and gas fired furnaces will be in operation.

Many different forms of thermo-couple mountings.

Impervite pyrometer tubes and chemical ware will be displayed and interesting demonstrations made of the imperviousness of this ware and its resistance to sudden temperature changes.

In charge of booth: E. S. Newcomb, J. H. Oetjen, H. L. Shippy.

A. Finkl & Son, Chicago. Space 43, will exhibit:

Molybdenum Die Blocks.

In charge of booth: William Finkl.

Firth-Sterling Steel Company, McKeesport, Pa. Spaces 104-105, will exhibit:

Blue Chip High Speed Steel.

Firth-Sterling Special Tool and Die Steel.

Firth-Sterling (S-LESS) Steel, which is proof against ordinary agencies of rust, stain and corrosion.

In charge of booth: E. T. Jackman, G. A. Jacobs, W. C. Royce, W. A. Nungester, I. Olsen, T. A. Larcey

J. B. Ford Company, Wyandotte, Michigan. Space 7, will exhibit:

Methods of agitating solutions with air.

Wyandotte Cleaning Specialties.

In charge of booth: B. N. Goodell.

Forging & Heat Treating, Pittsburgh. Space 64, will exhibit:

Publications.

In charge of booth: E. C. Cook, Mr. Yeager, Geo. Grant.

William Ganschow Company, Chicago. Space 9, will exhibit:

William Ganschow Company Type A, B and C Speed Transformers.

Direct Connected—Type A.

Right Angle Drive—Type B.

Vertical Drive—Type C.
Automobile Transmission Gears.
Spiral Bevel Drive and Differental Gears.
Noiseless Bakelite Timing and Rawhide Gears—for the Commercial Trade. mercial Trade.
Spur Gears for 1-inch Outside Diameter to 12 Feet Diameter 20-inch Face.
Bevel and Mitre Gears.
In charge of booth: F. J. Niedermiller, Detroit representative, 4835 Woodward Avenue, Detroit, Michigan.

General Alloys Company, Chicago. Space 44, will exhibit:
Q-Alloys.
Wireless Bulletins—all apparatus in booth.
In charge of booth: H. H. Harris, A. L. Grinnell.

General Electric Company, Schenectady, N. Y. Spaces 31-32, will exhibit:
Electrical Heating Apparatus for Steel Treating.
In charge of booth: C. L. Ipsen, H. Fulwider, C. T. McLaughlin.

Goddard & Goddard Company, Detroit, Mich. Space 7B, will exhibit:
Their line of special "Go and Go" Milling Cutters as adapted for various lines of milling, special attention being paid to cutters for railroad work, automobile work and general purpose milling.
In charge of booth: A. N. Goddard, President; C. S. Goddard, Sales Manager; R. T. Rice, Ohio Representative.

Geo. J. Hagan Company, Pittsburgh. Space 13, will exhibit:
Photographs of a number of installations of electric, coal fired and oil and gas fired equipments.
Complete operating results, also blueprints and specifications will be available.
Bulletins describing the several types of furnaces will be distributed.
In charge of booth: J. Sandberg, Manager Detroit Office; R. E. Talley, Chief Engineer; E. F. Cone, A. D. Dauch.

Halcomb Steel Company, Syracuse. Space 52, will exhibit:
Tool and Alloy Steels and products made therefrom.
In charge of booth: H. J. Stagg, Sam Spalding.

Houck Mfg. Co., Brooklyn. Space 118, will exhibit:
Burners and rivet furnaces.
In charge of booth: C. J. Schwenk.

Haynes Stellite Company, New York City. Space 56, will exhibit:
Rounds, squares and flats of Stellite bar stock.
Stellite welded tip tools.
Numerous special castings, which have been successfully applied as valves, dies, etc.
Automatic device for removing of surface flaws from "Hot steel billets." Stellite is used as the scraper and is the only metal known that will stand up under the terrific heat and abrasion encountered.
Stellite milling cutters of various types.
Stellite tipped lathe centers.
Special knives used for cloth cutting, rubber cutting, linoleum cutting, etc.
Assortment of drawing dies, extrusion dies, ring dies, etc.
In charge of booth: F. J. Frank, C. S. Baur, W. B. Robinson, D. C. Warren.

Heppenstall Forge & Knife Company, Pittsburgh. Space 11, will exhibit:
One Hammer Ram, machined complete.
Two Hammer Guides, rough machined.
One Sow Block, rough machined.
One Solid Head Piston Rod, rough machined.
One Annealed Die Block, in the condition in which it is shipped.
One Treated Die Block, in same condition.
One Hardtem Die Block, in same condition.
One Hardtem Die Block, cut in half and polished to show the effects of heat treatment.
One shear knife for shearing rounds, such as are used in a drop forge shop.
One shear knife for shearing shapes.

One enlarged photograph of 7000-lb. steam hammer installed in 1892 by Trethewey Manufacturing Co., predecessors of Heppenstall Forge & Knife Company.
Various difficult drop forgings which have been made from different grades of our die blocks.
In charge of booth: E. H. Graham, Detroit District; J. J. Cruice, Detroit District; A. L. Wurster, Philadelphia District; G. I. Allen, Cleveland District; C. W. Heppenstall, Treasurer and General Manager; Floyd Rose, Secretary and General Sales Manager.

Holcroft & Company, Detroit. Space 49, will exhibit:
Photographs; miniature designs for heating elements and furnaces; complete designs and drawings of electric furnaces and quench devices; also general information on all types of furnaces and ovens.
Also daily visits to plants where firm has electric furnaces in operation. These will be conducted personally by a representative of the company.
In charge of booth: F. J. Frank, C. S. Baur, W. B. Robinson, D. C. Warren, Treasurer; H. L. Ritts, Sales Manager; C. L. Joy, Chief Engineer.

Hoskins Manufacturing Company, Detroit. Space 63, will exhibit:
Pyrometers and Electric Heat Treating Furnaces.
Features will be a furnace with a new type of heating element, and automatically controlled by a new type of temperature regulator.
In charge of booth: C. S. Kinnison, W. A. Gatward, R. P. Ellis, J. D. Sterling, J. W. Moore, A. S. Lee.

E. F. Houghton & Company, Philadelphia. Space 33, will exhibit:
Oils, leathers and carburizing materials.
In charge of booth: Louis E. Murphy, George W. Pressell, C. W. Cressman.

International Nickel Company, New York City. Space 115, will exhibit:
Nickel and Nickel Products.
In charge of booth: Dr. Paul D. Merica, A. J. Wadhams, A. E. Turner.

Interstate Iron & Steel Company, Chicago. Space 40, will exhibit:
Various important parts of automobiles of different makes made from Interstate Alloy Steels.
In charge of booth: E. Larned, 104 S. Michigan Avenue, Chicago; W. J. MacKenzie, 104 S. Michigan Avenue, Chicago; Paul Llewellyn, 104 S. Michigan Avenue, Chicago; F. W. Guibert, Ford Building, Detroit; H. L. Couzens, Ford Building, Detroit; R. S. LeBarre, 104 S. Michigan Avenue, Chicago.

Iron Age, New York City. Space 15, will exhibit:
The Iron Age.
In charge of booth: F. J. Frank, C. S. Burr, W. B. Robinson, D. C. Warren, H. E. Barr, B. L. Herman, C. Lundberg, E. Findley, F. S. Wayne, D. G. Gardner, C. L. Rice, E. Sinnock, F. Schultz, W. C. Sweetser, A. L. Marsh, O. B. Bergersen, W. W. Macon, E. S. Cone, G. L. Lacher, S. L. Prentiss, R. E. Miller.

Keller Mechanical Engraving Company, Brooklyn. Space 5, will exhibit:
In operation, the New Type "F" Automatic Die Sinking Machine embodying striking revolutionary features; entirely electrically driven; push button controls for every movement; follows any contour, besides feeding horizontally or vertically; operation, Automatic, Semi-Automatic or by Hand. Original wood or plaster patterns can be used as masters. Heavy cutting with big mills.
In charge of booth: Jules Dierckx, S. A. Keller, Charles Bitter, A. J. Benson.

Keystone Refractories Company, New York City. Space 116, will exhibit:
Dura-Stix—the high temperature cement.
Crundumsand—a dense high refractory granular material.
These articles are used as refractories for furnace economy.
In charge of booth: F. W. Reisman, President; L. E. Turk, Treasurer; G. M. Sherman, New England Sales Manager; H. A. O'Brien, S. W. Cole, local representatives.

Charles Kleist & Son, Jamestown, N. Y. Space 19A, will exhibit:
Drop Hammer Boards for Board Drop Forge Hammers.
(a) Built-Up-Board—(New Principle).
(b) Cut-in-Board.
(c) Standard Board.

In charge of booth: H. Brewer, C. A. Martin, A. F. Moranty, G. W. Tall, Jr.,

Leeds & Northrup Company, Philadelphia. Spaces 39-57, will exhibit:

Potentiometer Pyrometers for indicating, recording, or signaling temperatures, or for the complete automatic control of temperatures.

Equipment for heat treating according to the Hump Method, both tool type and production type equipments.

Equipments will be in operation and actual hardening performed at the show.

In charge of booth: H. Brewer, C. A. Martin, A. F. Moranty, G. W. Tall, Jr., A. E. Tarr, Jordan Korp.

E. Leitz, Inc., New York City. Space 45, will exhibit:

The Well-known Leitz "*Micro-Metallograph*" in conjunction with the new Vibration Absorber, which solved a problem every Metallurgist had to combat with.

General Metallurgical Microscope Equipments with a full line of "*Apochromatic*" Objectives and "*Periplan*" Eyepieces.

Grinding and Polishing Machines for the preparation of microscopical specimens.

In charge of booth: G. Sauppe.

Machinery, New York City. Space 19B, will exhibit:

Machinery and its publications.

In charge of booth: J. N. Wheeler.

Midvale Steel & Ordnance Company, Philadelphia. Space 6, will exhibit:

Booth will be used primarily for reception purposes.

Special decorative features will advertise our complete line of carbon, alloy and high speed tool steels, etc.

In charge of booth: S. Hazlewood, Manager Forging Division; H. E. Rowe, in charge of Tool Steel Sales; R. E. Dexter, Manager Detroit District Office; G. A. Richardson, in charge of Advertising and exhibits, etc.

Midwest Steel & Supply Co., Inc., New York City. Space 55, will exhibit:

Midwest Unit Air Filters.
Midwest Compressor Type Filter.
Midwest Type "D" Filter.
Midwest Tractor Filter.
Midwest Steel Sections.
Midwest Inserts.
In charge of booth: A. M. Goodloe.

Montgomery Chemical Company, Detroit, Michigan. Space 72, will exhibit:

Their full line of Case Hardening Compound and method of manufacturing.

A miniature exhibit of part of our commercial heat treating department in Detroit.

In charge of booth: L. C. Dunn.

Motch & Merryweather Company, Cleveland. Spaces 2-3 and 4, will exhibit:

Complete line of Machinery in operation.

In charge of booth: Geo. Merryweather, Stanley Motch, Geo. Lawrence.

National Machinery Company, Tiffin, Ohio. Spaces 37-38, will exhibit.

Forging Machinery.

In charge of booth: E. F. Frost, F. J. Mawby, K. L. Ernst, F. W. Klenk, C. D. Harmon.

S. Obermayer Company, Chicago, Space 47 will exhibit:

Five grades of super refractories and high Temperature cements, showing their application in various types of furnaces, etc.

Various sizes and grades of charcoal, various sizes and grades of plumbago and graphite and various grades of refractories and shapes processed from refractories which we manufacture and various grades of polishing material, sand blast, sand, etc.

In charge of booth: J. L. Cummings; Mr. Geer, Detroit; Mr. Newman.

Ohio Machine Tool Company, Kenton, Ohio. Space 70 will exhibit:

Metal Working Shapers.

In charge of booth: C. C. Swift; R. D. Shields; Wm. Ochse; L. H. Peters; all of **Kenton,** Ohio.

Tinius Olsen Testing Machine Co., Philadelphia. Space 58 will exhibit:

Machines for applying impact tests; alternate stress tests, repeated impact tests, Brinell hardness test, special hardness tests for sheet metal both soft and hard.

Universal Testing Machines with various attachment for testing in tension, compression and transverse; ductility tests of sheet metal, hydrostatic tests; tests of welding material.

Special machines for determining ductility and drawing quality of sheet metal known as the Olsen Ductility Testing Machine.

Special equipment for testing welds and welding material known as the Owens Weld and Welding Material Equipment.

Various Extensometer, Strain Gauges and Instruments together with full data and details covering our Olsen-Carwen Static-Dynamic Balancing Machines for crankshafts, fly-wheels and other rotating parts, as used in the automobile and electrical world.

In charge of booth: R. B. Lewis, Engineering Department; T. Y. Olsen, Vice-President and Treasurer.

Pangborn Corporation, Hagerstown, Md. Space 29 will exhibit:

Cabinet Sand-Blast in operation.

Photographs of installations of various types of Sand-Blast.

Equipment in the Steel Treating Industry.

Various grades of Angular Steel Grit and Samson Steel Shot; dustless sand-blast abrasives in actual use in equipment demonstrating wearing qualities and finishes produced.

In charge of booth: John C. Pangborn, Vice President; H. D. Gates, Sales Manager; Chas. T. Bird, District Sales Engineer; W. C. Lytle, District Sales Engineer.

Park Chemical Company, Detroit, Michigan. Space 113 will exhibit:

Case Hardening Compounds for Carbonizing.

Cyanide Hardening Compounds for Cyanide Process.

Klean Heat for reheating bath.

Lead Pot Carbon for covering lead baths.

Quenching and Drawing Oils.

In charge of booth: D. W. Bauer; J. N. Bourg.

Penn Seaboard Steel Corporation, Philadelphia. Space 65 will exhibit:

Die Blocks; trimmer steel and heavy forgings.

In charge of booth: H. A. Baxter; D. J. Crowley.

Quigley Furnace Specialties Company, New York City. Space 109 will exhibit:

Hytempite—A plastic refractory material for bonding fire brick and other refractories. Its bonding qualities under severe temperature changes are demonstrated.

Carbosand—A highly refractory granular material for making rammed in linings, furnace bottoms, special tile, etc.

High Temperature Insulation—In brick, block, powder and cement form for retarding heat flow through furnace walls, ovens, and similar heated equipment.

In charge of booth: W. S. Quigley, President; W. H. Gaylord, Jr. Traveling Sales Manager; W. A. Toohill; H. M. Thompson.

W. S. Rockwell Company, New York City. Space 62 will exhibit:

Furnace models; catalogues; charts; photographs of installations.

In charge of booth: J. N. Voltman; C. D. Barnhart.

Rodman Chemical Company, Verona, Pa. Space 36 will exhibit:

"Carbo" Case Hardening Compounds.

"Sealright" Luting Material.

In charge of booth: Hugh Rodman, General Manager; G. A. Webb, Metallurgist, Detroit District Representative.

Shore Instrument & Mfg. Company, Jamaica, N. Y. Space 126 will exhibit:

Model C-1 Scleroscope Testing Set. Complete.

Model "D" Scleroscope Testing Set (Recording).

Pyroscope—Type "A".

Pyroscope—Type "B".

Durometer and Elastometer for plastic material as rubber, etc.

Local case—for selective carburizing.
Local hard—for selective hardness on tool steels.
Jigs and Fixtures for testing.
In charge of booth: F. G. Kendall, Hotel Griswold, Detroit, Michigan, Home address: Rosedale, N. Y.

Simonds Manufacturing Company, Lockport, N. Y. Space 51 will exhibit:
Steel bars and products; saws and knives.
In charge of booth: C. R. Paffenbach.

Spencer Turbine Company, Hartford, Conn. Space 20 will exhibit:
Spencer Turbo Compressors for supplying air for oil and gas burning industrial furnaces.
One Catalogue No. —, which will furnish air for all of the gas burning furnaces in operation and visitors will have opportunity to see machine operating under actual working conditions.
Smaller size machine, Catalogue, No. 1505.
Both of above machines are electric motor driven and form a complete integral unit.
In charge of booth: S. E. Phillips, Secretary; H. M. Grossman, Sales Manager; R. B. Richardson, Detroit Manager.

Standard Alloys Company, Pittsburgh, Pa. Space 124 will exhibit:
Ferro-vanadium
Ferro-uranium
Radium
In charge of booth: Hamilton Foley; D. H. Horne; H. A. Kraeling.

Standard Fuel Engineering Company, Detroit. Space 24 will exhibit:
Several types of tool hardening furnaces.
High Speed Furnace under heat.
Line of refractories including some very difficult shapes as well as high temperature cements.
In charge of booth: T. Q. Cleland; J. R. Dunne; E. B. Beeman; H. M. Bray.

Standard Steel & Bearings Incorporated, Philadelphia. Space 102 will exhibit:
Annular Ball Bearings—Single Row and New Style Double Row.
Steel Balls—Various stages of production.
Wire Wheels—Rudge-Whitworth.
In charge of booth: C. B. Wisenburgh, Western Sales Manager; B. H. Gilpin, Sales Engineer; L. A. Cummings, Chief Engineer; H. A. Johnston, Assistant to Sales Manager.

Surface Combustion Company, Chicago. Space 22 will exhibit:
Type-A-25 Gas Fired Oven Furnace for carbon or high speed steel hardening.
Volcano testing furnace for testing purposes at temperature up to 3400 degrees Fahr.—gas fired.
High pressure gas system showing operation of tunnel and impact type burners.
In charge of booth: W. M. Hepburn; A. L. Hollinger; S. R. Anderson.

Taylor Instrument Company, Rochester, N. Y. Space 110 will exhibit:
Electric Pyrometers—indicating and recording. Thermo Couples, Rotary Switches, Signaling Pyrometers, Pyrometer Controls, Pyrometer Switchboards, Oil Tempering Bath Thermometers, Molten Metal Thermometers, Laboratory Thermometers, Mercury Actuated Recording Thermometers, Gas Actuated Recording Thermometers, Mercury Actuated Recording Thermometers, Gas Actuated Recording Thermometers, Mercury Index Thermometers.
In charge of booth: G. A. Howell, Rochester office; H. A. Hohes, Coon Devisser Company.

N. & G. Taylor Company, Philadelphia. Space 60 will exhibit:
Drop Forgings made from N. & G. Taylor Steels.
In charge of booth: H. N. Taylor, Geo. T. Allen, A. L. Wurster.

United Alloy Steel Corporation, Canton, Ohio. Space 122-123 will exhibit:
Various Steel samples subjected to several heat treatments and tests.
U'LOY steels made into: Bearings, Air Hammers; track tools; oil drilling tools;

shovels; special springs; locomotive forgings; foundry equipment; automotive parts.
In charge of booth: H. H. Pleasance, Sales Manager; W. H. Wiewel, Assistant Sales Manager; J. D. Jones, District Sales Agent; R. Wykoff; J. White; F. W. Krebs; R. E. Sherlock; F. B. Mulvaney; Earl Davidson.

Vanadium Alloys Steel Company, Latrobe, Pa. Space 107 will exhibit:
Board showing tools and parts manufactured from our various grades of Steel from the following:
Ward Tool & Forging Company, Latrobe, Pa.;
Service Tool Company, Newark, N. J.;
John Bath & Company, Worcester, Mass.;
Urbana Tool & Die Company, Urbana, Ohio;
Scott-Spencer, Cincinnati, Ohio;
A. Hankey & Company, Rochdale, Mass.;
Alemite Die Casting Co., Chicago, Ill.;
Spindles:
Heald Machine Company, Worcester, Mass.;
Norton Company, Worcester, Mass.
Hardened and Ground Rolls:
A. Hankey & Company, Rochdale, Mass.
Gripper Dies:
Severance Mfg. Company, Pittsburgh, Pa.
In charge of booth: J. P. Gill, Chief Metallurgist; A. F. MacFarland, Detroit Manager, D. D. Dodd, Detroit Office; A. R. Henry, Special representative; W. R. Mau, District Manager, Chicago Office, J. H. Caler, Cleveland Office; R. R. Artz, Pittsburgh Office.

Vanadium Corporation of America, New York City. Space 103 will exhibit:
Space will be used as a reception room.
In charge of booth: M. G. Baker, Vice President; G. L. Norris, Metallurgical Engineer, J. A. Miller, Jr. all located at Statler Hotel; W. R. Flannery, 849 Book Building, Detroit.

Westinghouse Electric & Manufacturing Company, Pittsburgh. Spaces 17-18 will exhibit:
Full line of electric furnaces and controls in full operation; oven and space heaters; electric solder pots; tempering ovens; and display of Krantz safety switches.
In charge of booth: C. C. Boos; A. D. Turner; W. S. Scott.

Wilson-Maeulen Company, New York City. Space 46 will exhibit:
Rockwell Direct Reading Hardness Testers.
Tapalog, Pyrometers Recorder.
Monopivot Pyrometers.
In charge of booth: C. E. Hellenberg; Harvey Lee; Harry Goldsen.

Witherow Steel Company, Pittsburgh, Pa. Space 59 will exhibit:
Various types of Forgings and Forging blanks with finished pieces.
Also exhibit entitled, "The Evolution of an Axle."
In charge of booth: W. P. Witherow, President; G. P. Norton, General Manager of Works; W. C. Emory, Metallurgist; L. A. Daines, Sales Engineer.

SYMPOSIUM ON HARDNESS TESTING

THE Committee on Hardness Testing of Metals, Division of Engineering-National Research Council will hold an important symposium on Thursday afternoon, October 5 during the International Steel Exposition at Detroit.

This committee has already done a great amount of valuable work on the subject of hardness testing and this meeting of the committee will undoubtedly have very important results.

The symposium will be in charge of Major A. E. Bellis, formerly Metallurgist, U. S. Armory, Springfield, Massachusetts.

In order that all those who are interested in this work may have the opportunity of entering the discussion, the committee has prepared a questionnaire in the attempt to arrive at comprehensive views of the opinions of those who are interested in the subject both from a practical as well as a theoretical standpoint.

It is desired that all those interested prepare their answers to this questionnaire and forward them to Major A. E. Bellis, Blake and Valley streets, New Haven, Connecticut.

If there are any opinions that are not covered by this questionnaire, it is requested that these ideas be incorporated along with the regular answers. In order to avoid restriction of space it is suggested that answers to the specific questions be given simply under the question number and other remarks or expressions of opinion be given in additional paragraphs.

It is imperative that these answers go forward to Major Bellis at the earliest possible time so that they may be reviewed prior to the convention meeting.

The program for the symposium meeting will be as follows:

OBJECT OF COMMITTEES, INVESTIGATION AND QUESTIONNAIRE by Major A. E. Bellis, Chairman of Committee on Hardness Testing of Materials.

SIGNIFICANCE OF HARDNESS TESTS by Dr. H. P. Hollnagel, General Electric Company.

HARDNESS AND ITS RELATION TO MAGNETIC PROPERTIES by Professor R. S. Williams, Oberlin College.

Questionnaire on Hardness Testing of Metals

DEFINITIONS

QUESTION NO. 1. What is your understanding of the term "hardness" based on you experience?

QUESTION NO. 2. If you recognize more than one definition, will you state all of the characteristics which the term applies to you?

QUESTION NO 3. Do you originally distinguish between different specific types of hardness, and what are the types?

QUESTION NO. 4. Can you suggest terms which could be better applied to qualities now commonly classed under the general term of hardness?

Testing Practice

QUESTION No. 5 Do you use any of the several methods at present exemplified by machines on the market?

QUESTION NO. 6. Do you use a different type of hardness testing machine for different purposes?

QUESTION NO. 7. Have you a method other than those referred to? If so, is this a method of your own design? (Please give details.)

QUESTION NO. 8. Is it specialized for a particular purpose?

QUESTION NO. 9. Are you willing to describe its character?

QUESTION NO. 10. Have the methods which you have ordinarily used given entire satisfaction for all kinds of materials?

QUESTION NO. 11. What correlation do you find between various machines?

QUESTION NO. 12. In determining hardness acquired by heat treating operations from a full anneal to the maximum hardness obtainable in any one steel by different methods (such as full impression and rebound types) do you find a satisfactory parallel from results of the different machines? Have you any data on curves?

Practical Considerations

QUESTION NO. 13. Do you use hardness tests as means to an end in any way whatsoever?

QUESTION NO. 14. Do you use the hardness number or measure for itself alone, or is it used to predict strength?

QUESTION NO. 15. Do you make hardness tests for your own information or to satisfy customers specifications?

QUESTION NO. 16. How important do you find information obtained from hardness tests to be? (Give a series of degree or comparative adjectives, which are vitally important.) Dollars and cents. Give degree of importance, as: Absolutely essential, very important, necessary, not essential, but desirable, useful if reliable, etc. Can you give any monetary estimate of their importance?

QUESTION NO. 17. Do you use the hardness test as a means for checking production?

QUESTION NO. 18. What relation do you recognize between hardness and:—

(a) Resistance to wear
(b) Resistance to abrasion
(c) Resistance to fatigue
(d) Tensile strength
(e) Elasticity
(f) Compressibility
(g) Toughness
(h) Resistance to impact
(j) Drilling, planing, turning and various machining detail operations
(k) Tool presentation for best cutting conditions.
(l) Other properties of metals.

QUESTION NO. 19. Relationship between a surface and depth case hardness, such as a 1/16 thick case and a case hardness which goes all the way through a specimen?

QUESTION NO. 20. What is the maximum useful range of hardness tested for?

QUESTION NO. 21. Have you any information or theory on:

(a) The relation of hardness to penetrability by X-rays.

(b) The relation of hardness to crystal structure.

(c) The relation of hardness to magnetic properties

(d) The relation of hardness to specific heat, thermal conductivity, and such allied properties.

QUESTION NO. 22. The relation between hardness and amorphous content of metals.

QUESTION NO. 23. The relation between hardness and chemical activity.

QUESTION NO. 24. (a) Is there any relation between hardness and and hysteresis?

(b) Is there any relation between hardness and coercive force?

(c) Is there any relation between hardness and residual magnetism?

(d) Is there any relation between hardness and the lower temperature at which a substance may be heat treated. For instance, in the neighborhood of 200 to 300 degrees Cent. in steel.

QUESTION NO. 25. Is there a relation between hardness and specific gravity?

QUESTION NO. 36. Does increased hardness show a relationship with resistance to the change in specific gravity when the material is put under pressure?

Methods Relative to Use of Brinell Ball

QUESTION NO. 27. If you use the Brinell Ball for obtaining hardness:—

(a) What sort of machine is used for applying the load?

(b) What loads are used for various metals?

(c) What diameter of ball is used?

(d) Do you take account of rate of application of the load?

(e) How long is the load left on the specimen?

(f) Do you measure diameter or depth of impression?

(g) How is diameter or depth of impression measured?

(h) What basis is used for obtaining hardness number?

(*i*) *Do you use any fixed type of specimen test?*

General Conditions

QUESTION NO. 28. What development of industrial hardness tests apply to—

(*a*) *Tests for thin sheet metal?*
(*d*) *Tests on very soft metals such as lead?*
(*c*) *Tests as to the general workability of metals?*
(*d*) *Tests on very soft metals such as lead?*

NEW HONORARY MEMBER

PROFESSOR Henry LeChatelier, Paris, France, has been elected to Honorary Membership in the American Society for Steel Treating.

The celebration of the 50th anniversary of his scientific career was recently celebrated in Paris and at that time Professor LeChatelier was notified and accepted his election as an Honorary Member.

His letter of acceptance follows:

Paris, France.
March 5, 1922.

President Gilligan:-

I have been greatly pleased at the honor your Society has conferred upon me by electing me an Honorary Member. I am deeply touched at your thoughtfulness in having this election coincident with the celebration of my Fiftieth Scientific Anniversary.

Will you act as my interpreter to your colleagues and express to them my great apprecation of the sentiments of regard and good will which they have extended to me.

Kindly accept the expression of my highest regard.

(Signed) Henri LeChatelier.

The following account of the scientific career of Professor LeChatelier has been largely extracted from the "Metallographist."

Henry Le Chatelier

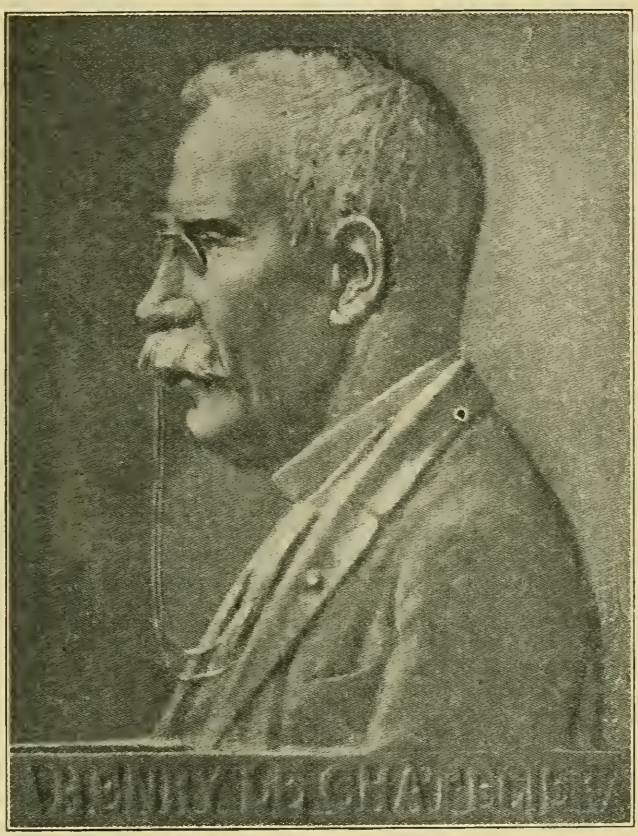
Henry Le Chatelier, so well known to all students of applied science, entered the Ecole Polytechnique at the head of his class in 1869. After graduating from this school in 1871, he spent three years at the Paris School of Mines, and upon leaving the School of Mines was sent to Algeria as a member of a commission whose mission was to ascertain the existence of a sea which was thought to have existed, in the past, in the deserts of Southern Algeria. Upon his return he practiced for two years the profession of engineer at the "Corps des Mines" of Besancon.

In 1877, Mr. Le Chatelier was appointed Professor of general chemistry at the Paris School of Mines, and in 1884 "interrogateur" at the Ecole Polytechnique, a position which he resigned in 1897. In 1884 he was the first choice of the Board of Improvement of the Ecole Polytechnique for the chair of Chemistry. In 1887 he gave up the chair of general chemistry at the Ecole des Mines to occupy that of industrial chemistry at the same school, a position which he still holds.

In 1892, he was awarded the Jerome Ponti prize, and in 1895 the La Caze prize.

In 1898, Mr. Le Chatelier was appointed Professor of mineral chemistry at the College de France, where he is the colleague of Professor Berthelot,

who occupies the chair of organic chemistry. Professor Le Chatelier is vice-president of the Chemical Society and of the Mineralogical Society; a member of the Committee of Applied Chemistry of the Societe d' Encouragement, foreign member of the Societe des Sciences of Holland, and member of many other scientific and technical societies. He is secretary of the Alloy Committee of the Society d' Encouragement, and the success of this important enterprise is due in a great measure to his untiring energy.



He is also the French member of council of the International Association for the testing of materials.

As Professor Le Chatelier himself says, the starting point of all his scientific investigations is to be found in his desire to apply scientific methods to industrial problems. Even his researches in pure science were suggested by industrial operations.

Professor Le Chatelier's scientific investigations and writings may be classified in two groups which at first sight appear quiet unrelated: Chemical Mechanics and Industrial Chemistry. These two departments of chemistry, however, as the author himself says, possess numerous points of contact. The laws of chemical mechanics control the phenomena of industrial chemistry as rigorously as they do the reactions in scientific laboratories.

His first researches dealt with hydraulic materials, and his numerous and valuable contributions to this important subject have given him a world-wide reputation among constructing engineers. The study of the dissociation of carbonate of lime was the starting-point of his researches in chemical mechanics as well as of those dealing with high temperatures.

Professor Le Chatelier's eminently successful researches dealing with the measurement of high temperatures are too well known to demand more than a passing notice. His thermo-electric couple is now in use in numerous industrial establishments where its usefulness could hardly be overestimated. This admirable pyrometer has made possible investigations of the greatest commercial and scientific importance in the physics of metals and alloys. The discovery by Osmond of the upper thermal critical points of iron and the scientific and systematic study of all the critical points of iron and steel, which have thrown so much light upon the constitution of steel, have been made possible by the use of the Le Chatelier thermo couple. Without it the construction of the fusibility curves of many metalic alloys, so invaluable in ascertaining the constitution of these alloys, would be a matter of great difficulty and much uncertainty. The discovery of the simple law connecting the temperature of the junction of the two metals and the electric current generated, which was the result of systematic and strictly scientific work is a monument which would satisfy the ambition of most physicists. Had Professor Le Chatelier done nothing more than this in the domain of pure and applied science, it would have sufficed to secure the gratitude and admiration of the scientific and industrial world. This discovery, however, which he has so generously presented to the world, constitutes only a relatively small part of his contributions to the advancement of science.

Professor Le Chatelier's investigations dealing with the setting of hydraulic material were the starting-point of his theoretical studies of the laws of solubility. These, in turn, suggested to him his experimental researches on the fusibility of mixtures of salts, and finally led him to investigate the constitution of metallic aloys, thus joining the ranks of those engaged in metallographic investigations. And we all know what valuable services he has already rendered both to the technology of the subject and to the interpretation of the results. Professor Le Chatelier showed that the fusibility curves of metallic alloys were in every way similar to the freezing curves of aqueous saline solutions or of mixtures of melted salts from which he inferred a similarity of constitution between these two classes of substances. These conclusions were in every particular confirmed by microscopical examination. According to the appearance of the curve of fusibility, he was led to classify all alloys into three groups, similar to those he had previously proposed for mixtures of salts, namely: (1) Alloys forming neither definite compounds nor isomorphous mixtures, (2) Alloys forming definite compounds and (3) Alloys forming isomorphous mixtures. To these three groups should be added a fourth one, including all alloys with abnormal curves of fusibility, and which future investigation will probably further subdivide. This modern theory of the constitution of alloys has been fruitful in deductions of industrial importance and will undoubtedly result in the abandonment of the empirical methods still in such extended use in the manufacture of metallic alloys.

After having thus studied the constitution of metallic alloys in general, it is quite natural that Professor Le Chatelier should have been attracted by the fascinating problem connected with the constitution of steel. To investigate this subject, he naturally adopted miscoscopical methods as one of the most promising means of advancing our knowledge of the true nature of steel. He entered this field exceptionally well equipped for effective experimental work. Fully aware of the importance of time-saving appliances in laboratory work as well as in industrial operations, he endeavored to shorten the required manipulations and especially to obtain some polishing powders which would greatly reduce the length of the polishing operation. The results of his investigations were published in full in the January, 1901, issue of "The Metallographist." He also devised a special microscope described in the same journal and recommended the use of the monochromatic light of a mercury arc vacuum lamp for photomicrography.

Professor Le Chatelier's discussion of the data upon which the modern theory of the constitution of steel has been erected is most valuable, notably his paper on "The Present Condition of the Theories of Hardening" and on "Iron and Steel from the Point of View of the Phase Doctrine," both of

which were published in full in "The Metallographist."

His experimental work dealing with the electrical resistance and with the dilation of steel, undertaken with a view of throwing additional light upon the allotrophic transformations of iron discovered by Osmund have yielded very important results. They have shown that the upper thermal retardation of iron (Ar3) occurring at about 850 degrees Cent., while often hardly noticeable by the calorimetric method, is on the contrary very marked when determined by the electrical method. This upper critical point always corresponds to an abrupt and very great alteration in the electrical resistance of iron. The second critical point on the contrary, occurring at about 750 degrees Cent., and the point of recalescence have hardly any effect upon the electrical resistance. His investigations on electrical conductibility were extended to nickel steel and to manganese steel, as well as to various non-ferrous alloys. They revealed the existence of some allotropic transformations in several alloys and notably in brass (at 730 degrees Cent.), in aluminum bronze (at 500 degrees Cent.), in zinc (at 350 degrees Cent.) and in an alloy of copper, iron and nickel (at 690 degrees Cent.).

It will be seen that besides being a distinguished metallographist, Professor Le Chatelier possesses many other titles; he has won an eminent position in several departments of pure and of applied science, through his experimental skill, scientific methods, erudition, and intellectual power.

Professor Le Chatelier has published over one hundred and twenty-five papers. He also wrote a book, in collaboration with Mr. Boudouard, on the "Measurement of High Temperatures," and translated into French the important work of Professor Gibbs on the equilibrium of chemical systems. The greatest number of his writings, by far, were published in the Comptes Rendus of the French Academy of Sciences, the others mostly in the Annales des Mines, the Revue generale des Sciences and the Bulletin of the Societe d' Encouragement."

The above is extracted from the "Metallographist" for October, 1901. Since that time Prof. Le Chatelier has continued his work and has contributed unstintingly to the advancement and improvement of the Metallurgy of Steel. Since 1901 he has written something over one hundred papers on metallurgical and allied subjects. In partial recognition of his work he has been awarded the Bessemer Gold Medal by the British Iron and Steel Institute.

THE EFFECT OF STRUCTURE UPON THE MACHINING OF TOOL STEEL

By J. V. Emmons

Abstract of Paper

This paper discusses the effect of the hardness and the structure of tool steel upon its machinability. Detailed observations have been made of the effect of the various structural constituents upon its machinability. The machining operations considered are turning, milling, drilling, reaming, thread cutting, swaging, wire drawing, punching and shearing.

General conclusions are drawn as to the most favorable structures for the various machining processes. Explanations of many of the difficulties encountered in machining tool steel are offered, and the way is pointed out for the development of annealing processes to secure the desired machinability.

IN THE manufacture of tools, the question of proper machinability is one of the highest importance. In the present age of quantity production, low machining costs are absolutely essential to the success of many tool making enterprises. The question of obtaining a suitable machined finish upon certain tools is often the deciding factor in the purchase of tool steel. The spoiled work due to unsatisfactory machining often causes losses which appall the tool maker. Often the feasibility of manufacturing delicate tools requiring a high degree of accuracy depends upon obtaining a tool steel of more than average machinability. The following observations were made in the course of a study of the effect of the structure of tool steel upon the various machining operations which were performed upon it. This work was begun in 1910 and extended through a period of about 5 years to 1915. The accuracy of the conclusions has been confirmed by their successful application to commercial work during the succeeding 7 years.

A great deal of confusion has arisen from the fact that steels which machine easily are called "soft" and those with which difficulty is encountered are called "hard." "Hard to machine" is a common expression in every machine shop. Actually, the meaning is "difficult to machine." The word hard, meaning difficult, is thus easily confused with the word hard meaning the property of mineralogical hardness. It is thus concluded that the softer the steel, the greater the ease of machining and vice versa the harder the steel, the greater the difficulty which will be encountered in cutting it. This conclusion is undoubtedly true in some cases, but the exceptions are so many and so important that it should not be considered as a general rule. For instance, the effect of the structure upon the machining properties of tool steel has been found to be so great than in many cases it overshadows the effect of the hardness. As a means of estimating the machinability of tool steel, a knowledge of the structure is fully as important as a knowledge

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A paper to be presented before the Detroit Convention, October 2-7. The author, J. V. Emmons, is metallurgist, the Cleveland Twist Drill Co., Cleveland, O.

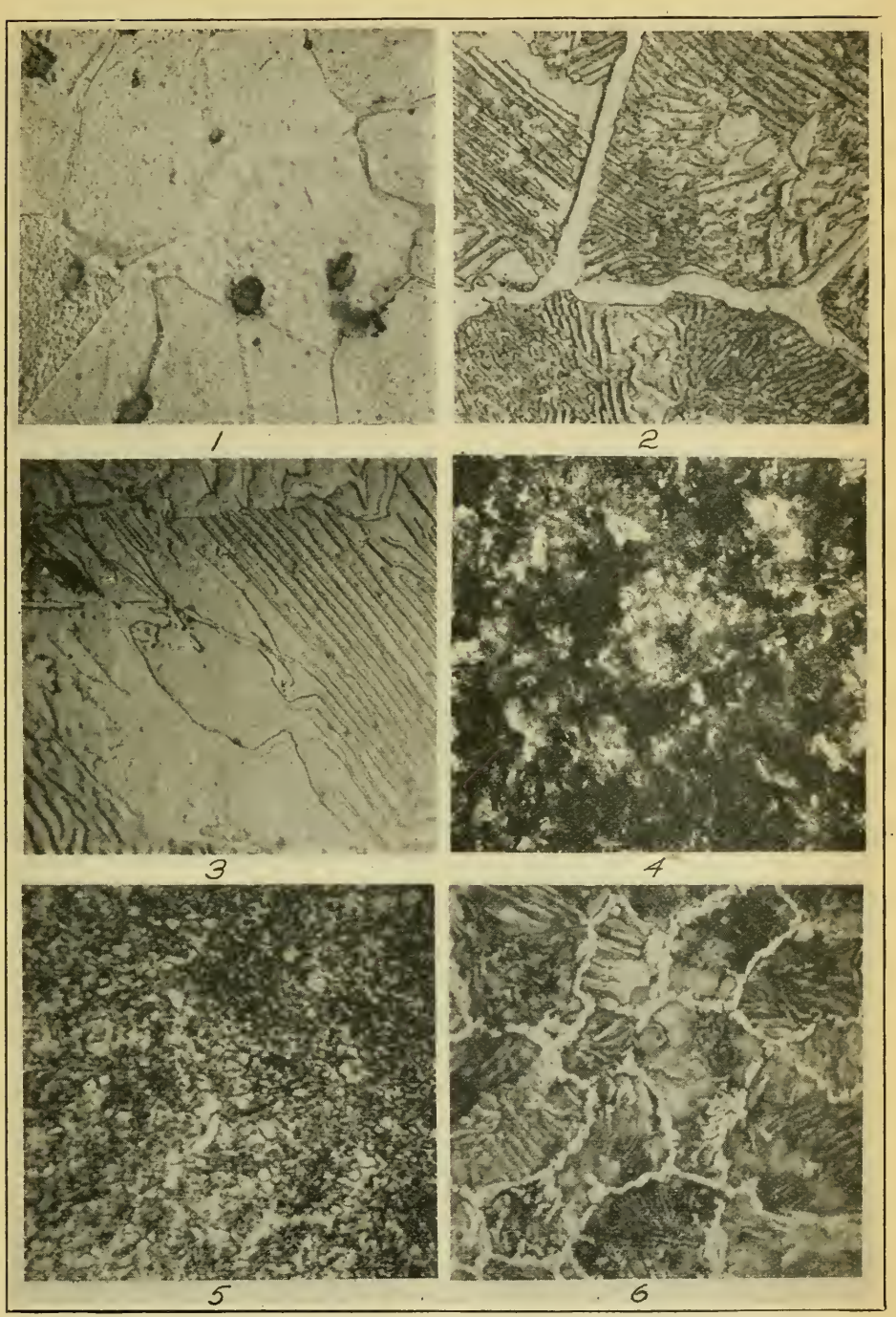


Fig. 1—The structure of pure ferrite. X 750. Fig. 2—Large network of massive cementite. X 750. Fig. 3—Pearlite showing both longitudinal and cross sections of the plates. X 750. Fig. 4—Sorbite. X 75. Fig. 5—Sorbite with rounded particles of massive cementite. X 1500. Fig. 6—Pearlite with network of massive cementite. X 1500.

of the hardness. A study of both hardness and structure together gives an index to the machinability of tool steel of surprising accuracy.

The series of experiments, the results of which are herein embodied was planned to show the detailed effect of the various microconstituents upon the machinability of the steel. Austenite, martensite and troostite were eliminated from consideration as they are obviously too difficult to machine to be considered a commercial possibility. The field was thus narrowed down to a consideration of sorbite, pearlite, ferrite, massive cementite and spheroidized cementite. The investigation is based upon plain carbon steels containing over 1.00 per cent carbon and no added alloy. Any deviation from these conditions is noted specifically. The machining operations under observation were: turning, milling, drilling, reaming, thread cutting, swaging, wire drawing, punching and shearing. The nature of each of the above mentioned microconstituents should be briefly reviewed in order to understand its effect upon a cutting tool.

Ferrite

Ferrite being carbonless iron is very soft and easily cut. It is also tough and easily deformed. In tensile tests, it has a high elongation and reduction of area. If pure its behavior during machining is that it cuts easily and with little wear upon the cutting tool. It is especially liable to gum up the tool, adhering to the cutting edge, creating excessive friction and frequently generating sufficient heat in this manner to draw the temper of the cutting tool. It also tears badly due to its great tenacity, particularly when cut with tools having little clearance and rake such as milling cutters and threading dies. This tearing, together with the friction of chips adhering to the cutting edge produces a rough finish very unsatisfactory for most requirements. The microstructure of commercially pure ferrite is shown in Fig. 1.

Cementite

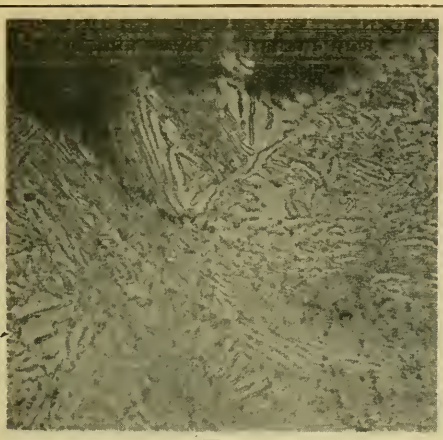
Cementite or carbide of iron is very hard and brittle. It is too hard to be cut by the average cutting tool and in tool steel can only be broken and pushed to one side by the advancing cutting edge. Due to its great hardness, it abrades the cutting tool very rapidly. The larger the cementite particles, the rougher the machined surface will be. A distinction can sometimes be made in the kinds of cementite as follows: 1. Massive cementite is that portion in excess of the amount required to form pearlite. It is usually present in larger masses than the eutectoid cementite and frequently forms a network at the grain boundaries. 2. Spheroidized cementite is the product of the precipitation of the eutectoid cementite in rounded or globular form, shown in photomicrograph Fig. 2.

Pearlite

Pearlite being a definite alloy which consists of alternate plates of ferrite and cementite, unites the toughness of the former with the hardness of the latter. Pearlite, therefore, tears badly, leaving a rough surface and at the same time wears out the cutting tool rapidly. The microstructure of pearlite is shown in Fig. 3.

Sorbite

Sorbite, due to its combined hardness and tenacity exerts a great abrasive action upon the cutting tool wearing it out rapidly. Due to the fine state of division of its cementite particles, it is possible to produce a very smooth finish upon the machined surface. Fig. 4 shows the structure of sorbite at 75 diameters magnification. While these observations are interesting, it should be noted they are made in reference to the pure unmixed constituents.



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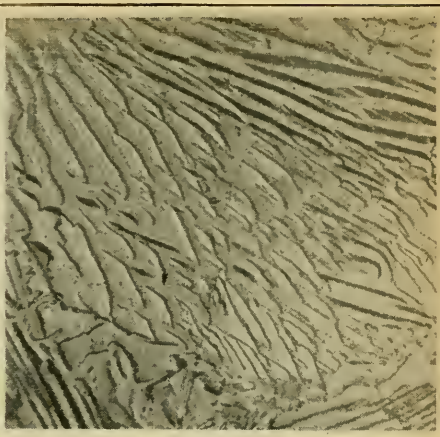

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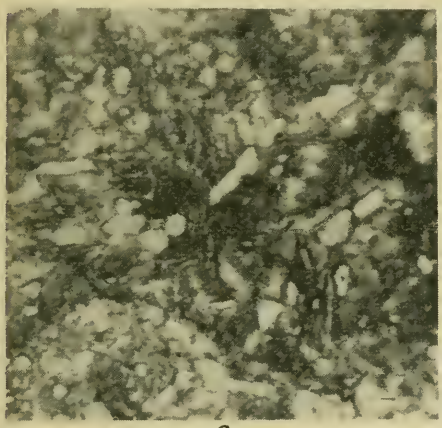

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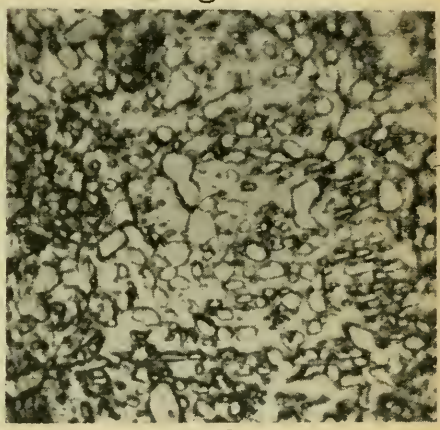

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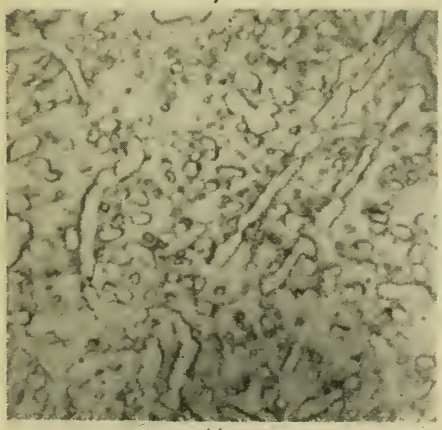

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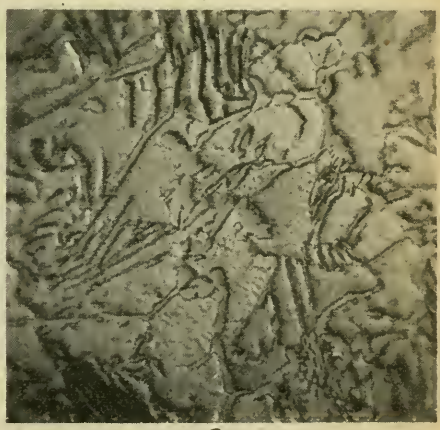

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Fig. 7—One edge of crack passing through pearlite. X 375. Fig. 8—Illustrating tendency of cementite plates to break into sharp splinters. X 750. Fig. 9—Pearlite, sorbite, and massive cementite. X 1500. Fig. 10—Sorbite, ferrite, spheroidized and massive cementite. The sorbite is well coagulated. X 1500. Fig. 11—Ferrite and massive cementite in large masses. X 1500. Fig. 12—Partially spheroidized cementite with about 50 per cent pearlite. X 750.

Annealed tool steel invariably consists of a mixture of not less than two and sometimes more of these constituents. The problem is thereby somewhat complicated. The most common combinations met with are as follows:

1. Sorbite and massive cementite.
2. Pearlite and massive cementite.
3. Pearlite, sorbite and massive cementite.
4. Sorbite, ferrite, spheroidized and massive cementite.
5. Pearlite, ferrite, spheroidized and massive cementite.
6. Ferrite, spheroidized and massive cementite.

These will be considered in more detail. It should be noted that the first three combinations are difficult to machine and are generally to be avoided. The latter three all have specific uses and from them satisfactory structures can be selected for almost every machining operation.

Sorbite and Massive Cementite

"Sorbite and massive cementite" are formed by two common processes. The first consists of cooling the steel from above the critical point with moderate rapidity. The second consists of quenching the steel from above the critical point and then drawing back to about 1200 degrees Fahr. This combination has a scleroscope hardness of 40 to 50 and a Brinell number of from 210 to 300. It can be machined, if slow speeds are used and the tools reground frequently. The finish produced is smooth and for this reason it has been sometimes used for the production of taps and thread gages where a smooth finish is essential. Satisfactory wire can be drawn from it as its ductility is high. Turning, milling, drilling and thread cutting can all be performed if care is taken, but the speed will be of necessity slow and the tool cost high. Swaging, punching and shearing, present such difficulties that it is scarcely feasible to even attempt them. In order to secure a satisfactory smoothness of finish which is the only possible excuse for using this structure, it is essential that the massive cementite be broken up into as small particles as possible and especially it must not be present in the form of a network. Fig. 5 shows sorbite and massive cementite at 1500 diameters magnification.

Pearlite and Massive Cementite

"Pearlite and massive cementite" is a combination that appears to make no friends among the machining operations. Fig. 6 shows a photomicrograph of this structure taken at 1500 diameters magnification. It turns rough and wears out the tools rapidly. It tears badly in milling and thread cutting. Drilling can be done successfully, if the drills are reground frequently. Reamers, however, are worn undersize with great rapidity. In swaging and wire drawing, the dies wear rapidly and the finished size will not run uniform. In punching while shearing there is apt to be a serious loss due to the stock cracking and the punches and dies wear out with great rapidity. This behavior of pearlite and massive cementite is so marked that a special investigation has been made to throw more light upon the reasons for its unsatisfactory machinability. The hardness of this combination varies from 40 to 46 scleroscope and from 220 to 300 Brinell being in this respect not much different from the sorbite and cementite combination. It is, therefore, obvious that the marked differences in machining behavior between the two combinations are not due to the hardness.

A careful examination of pearlite structures revealed the facts that pearlite is always present in grains of considerable size; that cracks

passing through pearlite prefer to follow the grain boundaries or if they pass through the grains to follow the laminations, as in Fig. 7. It was also observed that a cutting edge working in pearlite is usually preceded by a crack which runs ahead of the advancing edge as it wedges its way through the steel. The reason for the rough surface of machined pearlite was then apparent, that is, the machined surface is actually the rough fracture of the pearlite grains torn apart by tension. The rough surface is, however, more or less smoothed down after the initial rupture by the following cutting edge shearing off the high points.

The other peculiarity of pearlite, namely, its greater abrading action than sorbite of the same hardness is explained as follows: The cementite particles in sorbite are for the most part in round or rounded forms. The abrasive action of sorbite may, therefore, be likened to that of a grinding wheel with round emery for the abrasive. The cutting edge as it advances pushes the round cementite particles to one side and they slide readily over it. In pearlite, however, the cementite particles are in the form of flat plates of considerable size. As the cutting edge advances, the metal becomes distorted under the extreme pressures and the brittle cementite plates are broken into countless sharp cornered splinters. These sharp splinters firmly held in the matrix of ferrite exert an abrasive action similar to that of a grinding wheel with sharp emery for its cutting medium. The result is that the cutting tool is worn away with great rapidity. Fig. 8 shows this structure at 750 diameters magnification.

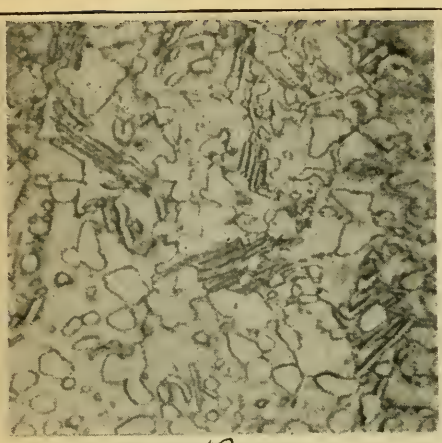
In this connection the observation should be recorded that massive cementite when present with the pearlite in a large network seems to increase the wearing effect upon the cutting tool very materially. This is probably due to the large size of the cementite splinters formed by the crushing of the network. It has also been observed that the higher the carbon content of the steel when in the pearlitic condition, the greater wear upon the cutting tool. This is undoubtedly due to the increased percentage of massive cementite with the corresponding increase in the number of abrading particles. From the above observations, the simple rule has been deduced; that the larger the grain size and more distinctly lamellar the pearlite, the greater the difficulty of machining. In practice this rule has been found to hold almost without exception.

Pearlite, Sorbite and Massive Cementite

The combination of pearlite, sorbite and massive cementite is not of such common occurrence as the preceding combination. It is, however, frequently found in steel that has been normalized, that is, heated considerably above the critical point and either air cooled or semi-annealed by plunging in line or ashes. Fig. 9 shows this structure at 1500 diameters magnification. This combination is machinable if slow speeds and extra hard tools be used, but it would be difficult to get any reasonable production from it. While its hardness is usually somewhat greater than that of pearlite produced by a slower cooling, it is somewhat easier to machine because the pearlite has not had time to assume a coarsely lamellar structure and the massive cementite has not been rejected to the grain boundaries to form a network. The principle reason for intentionally producing this structure would be to obtain a quick anneal where time was of more importance than ease of machining.

Sorbite, Ferrite, Spheroidized and Massive Cementite

The combination of sorbite, ferrite, spheroidized and massive cementite is the hardest combination that it has been found feasible to machine in reg-



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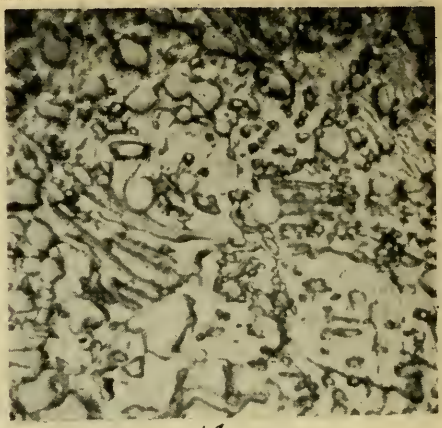

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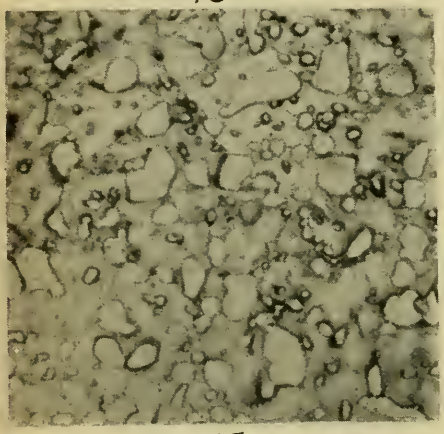

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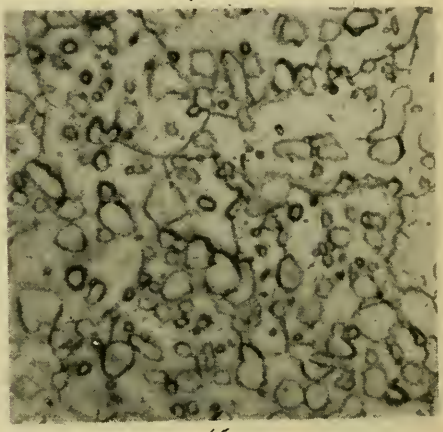

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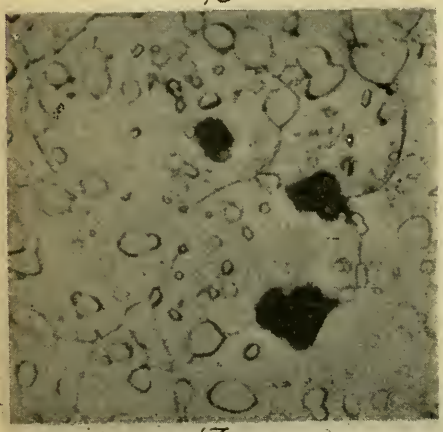

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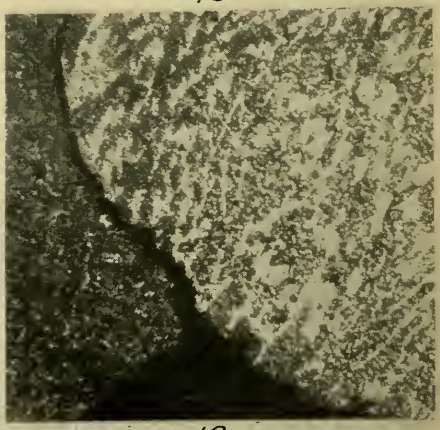

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Fig. 13—Partially spheroidized cementite with about 25 per cent pearlite. X 1500. Fig. 14—Partially spheroidized cementite with trace of pearlite remaining. X 1500. Fig. 15—Completely spheroidized cementite. No ferrite grains. X 1500. Fig. 16—Completely spheroidized cementite. Ferrite shows grain structure. X 1500. Fig. 17—Completely spheroidized cementite. The ferrite shows grain structure. Graphite beginning to precipitate. X 1500. Fig. 18—Portion of an oval segregation of cementite. The normal structure of the piece is shown upon the left. X 75.

ular production work. It is produced commonly by two methods: First by reannealing steel which has been previously spheroidized at a temperature only slightly above the Ac point and then cooling with moderate rapidity. The second method is to add an element such as chromium which tends to prevent the formation of lamellar pearlite. With such alloy steels the sorbite persists through much slower cooling than is the case with carbon steels. The coagulation of the sorbite also requires a much longer time, so that it is frequently uncompleted with ordinary annealing, Fig. 10.

This combination is machinable in proportion to the completeness with which the sorbite has coagulated. This is believed to be on account of the cementite particles becoming fewer and more rounded. It is sometimes quite difficult to determine when the sorbite has completely passed over into the spheroidized condition. As the coagulation proceeds, the ferrite areas at the same time become larger and more continuous, thus affording an easier passage for the cutting tool and lessening the abrasive effect. The machined surface of this combination is usually very smooth unless the coagulation has proceeded so far that the cementite has gathered in large masses separated by large areas of ferrite as shown in Fig. 11. In this case the steel is apt to machine gummy and tear easily. This tearing is particularly noticeable if the ferrite has begun to assume its characteristic grain structure with well marked grain boundaries. While a very large tonnage of steel with this structure is machined by all the common machining operations, it must still be regarded as inferior in machinabilty to the next combination to be considered.

Pearlite, Ferrite, Spheroidized and Massive Cementite

This is the most interesting combination of all the structures in tool steel because of its great variations in machinability, according to the percentage of the various constituents present. This structure is produced by slow cooling through the critical range to allow the slow deposition of the cementite from solution upon the massive cementite. When the Ar point is passed only enough cementite remains in solution to form a broken lamellar structure of pearlite. It is necessary that the cooling be sufficiently rapid to prevent the complete spheroidization of the cementite. All variations of this structure may be produced at will by varying the rate of cooling between the Ac and the Ar points. With a high percentage of pearlite the steel machines with practically all the difficulties noted in the case of the combination of "pearlite and massive cementite." As the percentage declines, however, the machining becomes more satisfactory. When the pearlite occupies about 50 per cent of the area, the machined surfaces become more smooth, particularly with the milling and thread cutting operations. This structure is shown in Fig. 12. The wear on the tools is, however, still quite heavy. Steel in this condition usually causes complaint from the turning, swaging, punching and shearing operations because of the frequent re-sharpening required by the tools and dies. The milling and thread cutting operations are, however, usually well satisfied because the satisfactory finish upon the work more than compensates them for the extra wear on the cutting edges.

When only about 25 per cent of lamellar pearlite remains, we have a structure of peculiar interest because it seems to be a happy medium which gives general satisfaction to all of the machining operations. (Fig. 13.) The turning is smooth and can be performed rapidly with a reasonable amount of production between regrinds of the tools. The milling is also smooth and free from tearing even at high speeds and heavy feeds. Thread cutting

is also satisfactory, the threads being sharp and clean with little burr. Drilling, reaming and other operations can be performed with satisfactory results. The peculiarly satisfactory results obtained from this structure are due to the fact that the eutectoid cementite is now almost completely broken up into rounded masses which no longer wear out the cutting tool with their former rapidity. The massive cementite is also in rounded masses easily pushed aside by the cutting edge. The ferrite areas are developed just sufficiently to allow easy passage to the cutting edge, but not enough to make it gum up and tear. While this structure appears to be the most satisfactory one when all the different operations are done upon one piece, it does not necessarily follow that it is the most satisfactory one for each and every operation. In fact, turning, swaging, drilling and frequently punching and shearing will have their requirements better satisfied with a softer steel.

The hardness with 25 per cent pearlite is about 32 to 38 scleroscope, while the Brinell is from 190 to 230. In order to secure a softer steel the spheroidization is pushed forward to completion. This reduces the scleroscope hardness to about 28 to 32 and the Brinell number to about 170 to 190 at the point where the last traces of pearlite laminations are disappearing as shown in Fig. 14. This change has been found to improve the machinability with respect to turning, drilling, swaging, punching and shearing. The milling and thread cutting, however, show increased roughness of surface and tendency to throw up a burr. Any further progress of the spheroidization removes the last traces of the pearlite laminations and leaves us with the last one of the structures of particular interest in machining.

Ferrite, Spheroidized and Massive Cementite

The structure now consists of rounded particles of cementite imbedded in a matrix of ferrite. (Fig. 15.) The ferrite, however, may or may not have developed its typical grain structure. (Fig. 16.) Steel of this structural type which has well developed ferrite grains is in the softest state it is possible for it to acquire without destroying some of its quality. In order to produce this complete spheroidization, it is necessary to prolong the time in passing through the Ac to the Ar region to a considerable length. Several hours are sometimes necessary to insure that the formation of pearlite is completely inhibited. This structure has a scleroscope hardness of from 25 to 32 and a Brinell hardness from 160 to 190.

For the operations of turning and swaging, this structure is ideal. For the other operations it is usually found too soft. Thread cutting is almost out of the question on account of the steel tearing badly and the tool hogging in. Milling is almost as bad, the soft gummy chips clogging the cutters and producing rough work. Steel with this structure is almost invariably pronounced hard in milling and tapping. This is a typical example of steel which is called "hard" when the actual meaning is "difficult to machine." Drilling can be performed successfully, but there is always a tendency for the drill point to hog in, or grab, breaking the drill. Reaming must be done carefully with a good lubricant as the gummy chips tend to ahere to the cutting edge producing rough holes. This structure performs well in wire drawing, but in punching and shearing the deformation is frequently excessive. It should be here noted that attempts to produce this structure of completely spheroidized cementite by slow cooling through the critical range if carried to extremes will result in the precipitation of part of the carbon as graphite, as shown in Fig. 17. This formation of graphite if in any considerable quantity renders

the steel inferior, if not actually useless due to its diminished hardening power. Great care is, therefore, necessary if this structure is to be produced upon a commercial basis.

In conclusion there are two freak structures which frequently cause considerable difficulty in the machining of tool steel. The difficulty is in-

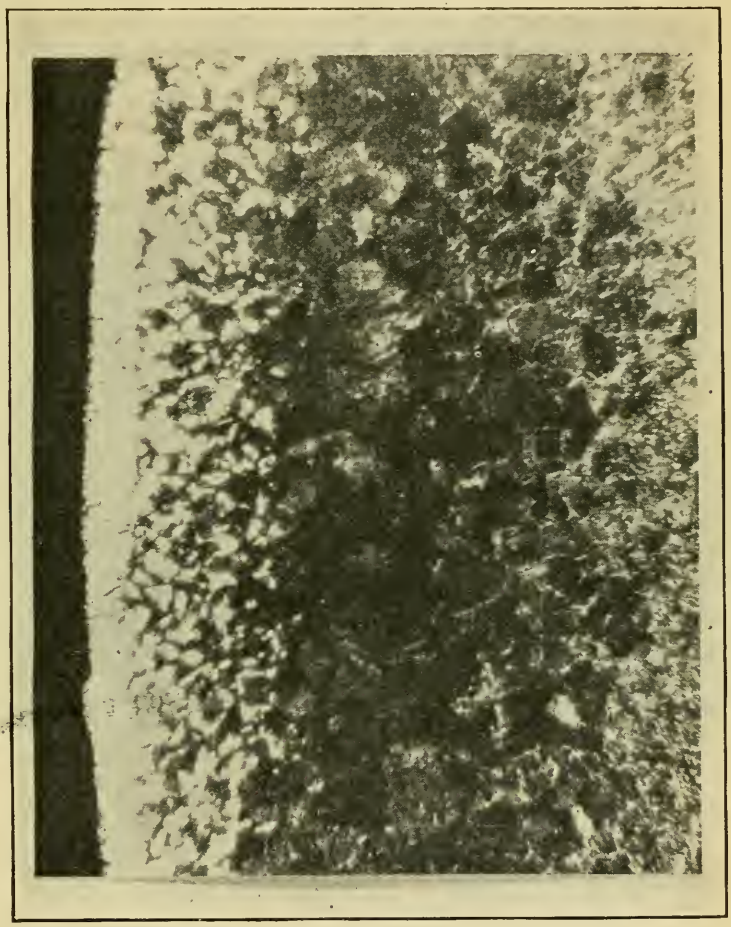


Fig. 19—Decarburized bark. Outside of the bar is on left. Normal structure of interior on extreme right. X 75.

creased by the fact that their presence is often unknown and hard to detect. I refer to segregations of cementite and to surface decarburization, or as it is commonly known, "bark."

Cementite Segregations

Hard spots are frequently met with in machining tool steel. These spots instantly dull or destroy the cutting edge of the tool. In the majority of cases these are found to be cementite segregations. Cementite segregations are difficult to detect unless they are present in large numbers, when they can be best located by the microscope. See Fig. 18. It occasionally happens that a few segregations in a lot of steel otherwise of satisfactory machinability

dull the tools in a manner that makes the true cause very difficult to locate. In such a case, the hardness tests and the microstructure may both appear good and the investigator is at a loss to explain why the steel should behave so badly.

Decarburized Bark

Decarburized bark has of necessity a structure different from the interior of the steel and, therefore, behaves differently in machining. Bark is never considered to be beneficial to a machining operation, but is a defective portion to be removed by machining. Fig. 19 shows this defect. Turning, shaping and planing are the principle operations to be affected by the

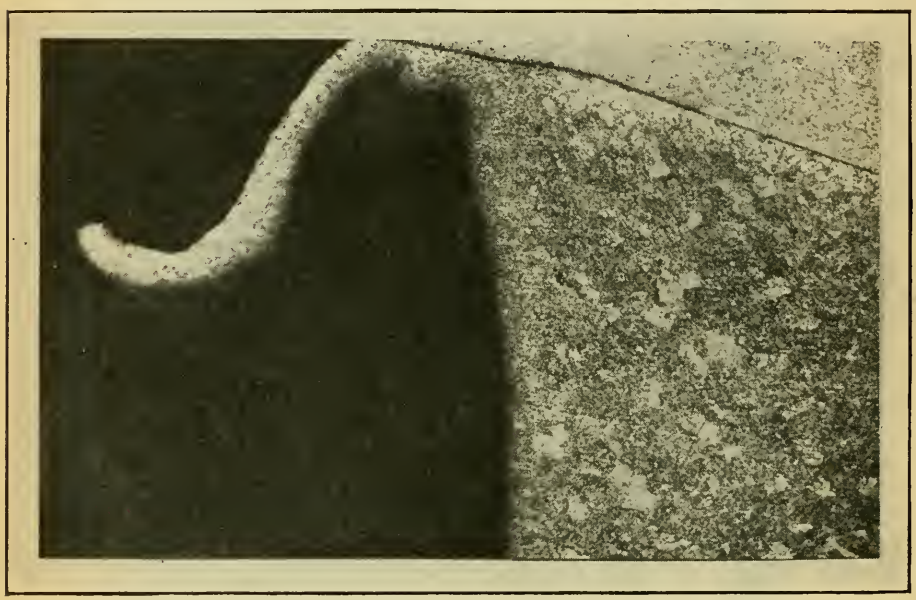


Fig. 20—Heavy burr in milling caused by slight ferrite bark. X 150.

bark. Even when the interior of the steel is completely spheroidized, the bark frequently contains a large percentage of lamellar pearlite which wears out a tool with great rapidity. An interesting phenomenon is frequently noted when the outside of the bark consists of a band of pure ferrite below which is a layer of pearlite and below this the more or less spheroidized interior of the steel. When a round bar having such a bark is turned, the pearlite ring constantly revolving against the same portion of the lathe tool actually wears a nick in the tool, while the portion of the tool cutting on each side of the pearlite is unaffected. The presence of bark especially a ferrite bark frequently causes a heavy burr in milling even though the interior of the steel may be in perfect condition to mill. This condition is shown in Fig. 20.

Conclusion

To sum up the observations detailed above, it may be stated that when a single machining operation is to be performed upon tool steel and the

(*Concluded on page* 1212)

CASE HARDENING

By A. H. d'Arcambal

Abstract of Paper

Tests conducted on samples of low carbon steel, cyanide treated, showed that the hardness obtained on cyanide hardened parts is due both to the absorbed carbon and nitrogen, principally to the latter (iron nitride). The higher the temperature (up to 1550 *degrees Fahr.) and the longer the time of immersion, the greater percentage of these two elements were found. The combined nitrogen in the areas of highest nitrogen concentration appeared as pearlite patches and in the less concentrated sections as needles.*

Izod notched bar tests, conducted on plain carbon and alloy case hardening steels, showed that of the specimens carburized and double treated, the S.A.E. 6120 *steels gave the highest impact readings, closely followed by the S.A.E.* 2315 *steels. The S.A.E.* 3115 *steels gave the lowest readings of the alloy steels tested. The S.A.E.* 1015 *and* 1112 *steels gave very low readings after carburizing and double quenching. All of the alloy steels showed lower impact readings after carburizing and single quenching for case refinement only, than was found on the specimens double treated after carburizing. The core fractures on the single treated specimens also showed a coarse grained structure, as compared with the fine grained fractures obtained on the double treated specimens.*

Impact tests were also conducted on the different types of steels, packed in sand instead of carburizing compound, and then double and single treated. The results on these double treated specimens ran as follows, from highest to lowest S.A.E. 1015, 6115 1112, 2315 *and* 3115. *The high results obtained on the* 1015 *and* 1112 *specimens were due to the softness of the material* (150-200 *Brinell*), *as compared with the hardness obtained on the alloy steels* (250-400 *Brinell*).

Static tensile tests on specimens of S.A.E. 6120 *and* 1015 *steels, sand treated, then double and single quenched showed that while greater tensile strength was obtained on the single treated specimens, this increased strength was gained at the expense of the ductility of the material.*

* * *

This paper on Case Hardening is divided into 2 parts, the first part being a study of the chemical reactions taking place in the cyanide process of case hardening, the remainder of the article giving the results of Izod notched bar tests on several well known types of case hardening steels.

Part I

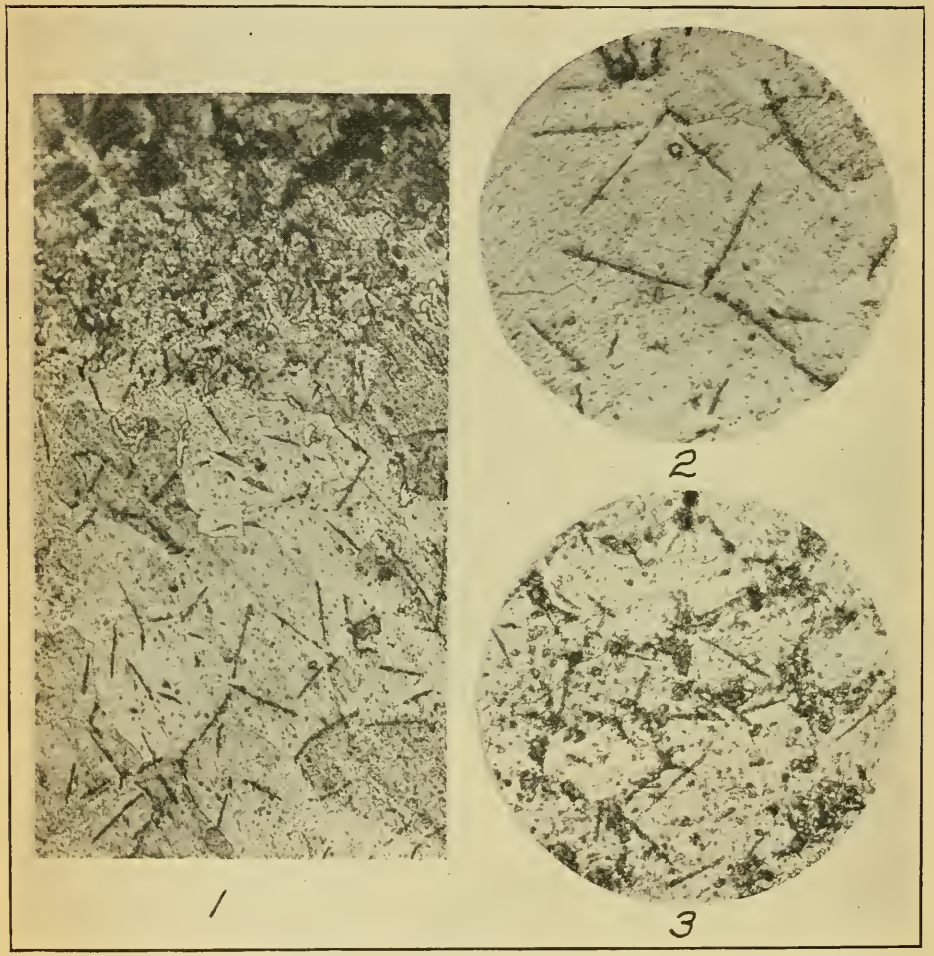
VERY few articles have been published on the true action of cyanide in the case hardening of steel. Papers by Brophy and Leiter[1], Hillman[2], and Shimer[3], attack this interesting subject from different angles and contain valuable information to all interested in the cyanide process of case hardening. In order to obtain additional information as to the chemical reactions occurriing in the cyanide hardening of steel, tests were conducted on

1, 2, 3. See foot note next page.

A paper to be presented before the Detroit Convention, October 2-7. The author, A. H. d'Arcambal, is metallurgist, Pratt & Whitney Co., Hartford, Conn.

samples of plain carbon case hardening steels, the results of these tests being given in Table I and photomicrographs in Figs. 1, 2 and 3. The following information is gained from these tests:

1. Steels given the cyanide treatment are both carburized and nitrogenized, the resulting hardness however, being due principally to the



CYANIDE TREATED SPECIMENS

Fig. 1—S. A. E. 1015 steel. 1 inch round specimen immersed in 76 per cent sodium cyanide bath at 1550 degrees Fahr. for 90 minutes, lime cooled, reheated to 1500 degrees Fahr., brine quenched, then annealed at 1600 degrees Fahr. X 250. Fig. 2—S. A. E. 1015 steel. Same as above. X 500. Fig. 3—S. A. E. 1112 steel. ⅜-inch round specimen immersed in 76 per cent sodium cyanide bath at 1550 degrees Fahr. for 100 hours, lime cooled, reheated same as specimen Fig. 1. X 500.

absorbed nitrogen, as the carbon is too low to produce file hardness. As medium carbon steels containing over 0.045 per cent nitrogen possess no ductility whatsoever[4], one can thus see the cause of brittleness in cy-

1. "True Action of Cyanide in Case Hardening of Steel," by Brophy and Leiter." *Transactions* of the American Society for Steel Treating. Vol. I, No. 6.
2. "Efficiency of Different Mixtures for Cyanide Hardening," by V. E. Hillman. *Transactions* of American Society for Steel Treating. Vol. II, No. 4.
3. "Cyanide in Liquid Case Hardening," by P. & E. B. Shimer. *Transactions* of the American Society for Steel Treating. Vol. II, No. 5.

anide treated objects. It is claimed that nitrogen causes greater brittleness in higher carbon steels than in steels of low carbon content. We can therefore see the folly of using a cyanide bath for reheating carburized specimens or as a heating medium for carbon tool steels.

2. The amount of carbon and nitrogen absorbed is dependent on the time and temperature, the higher the temperature and longer the time,

Table I

Carbon and Nitrogen* Determinations in Per Cent

Specimen No.	Treatment	1st .010-inch removed from O.D. Car.	Nitr.	2nd .010-inch removed from O.D. Car.	Nitr.	3rd .010-inch removed from O.D. Car.	Nitr.	4th .010-inch removed from O.D. Car.	Nitr.	Center drillings** Car.	Nitr.
1	45 mins. in cyanide bath at 1550 degrees Fahr. cooled in lime.	.44	.353	.22	.036	.18	.017	.14	.009	.14	.006
2	75 mins. in cyanide bath at 1550 degress Fahr. cooled in lime.	.52	.372	.32	.048	.21	.028	.14	.013	.14	.006
3	120 mins. in cyanide bath at 1550 degress Fahr. cooled in lime.	.56	.451	.39	.077	.19	.029	.15	.014	.14	.008
4	45 mins. in cyanide bath at 1450 degrees Fahr. cooled in lime.	.30	.215	.22	.044	.15	.027	.15	.019	.14	.009
5	220 mins. in cyanide bath at 1450 degrees Fahr. cooled in lime.	.61	.467	...	...	...	...	...	...	...	...

76 per cent sodium cyanide used.
Size of test pieces—1¼-inches dia. x 8 inches long.
Analysis of steel used for the test specimens—

Carbon	.14	per cent
Manganese	.62	per cent
Phosphorus	.020	per cent
Sulphur	.064	per cent
Nitrogen	.0033	per cent

*—The method of analysis used is the one recommended by the bureau of standards and gives only the combined nitrogen (iron nitride).
**—¼-inch drill used.

the greater percentage of these two elements are found.

3. The highest concentration of nitrogen and carbon is found in the first 0.005-inch layer removed from the outside diameter of the cyanide treated specimens. The second layer removed from the samples contain less than 1/5 the amount of combined nitrogen found in the first layer.

4. Nitrogen penetrates the material to a slight extent throughout the cross section as is shown by the analysis of the center drillings.

5. The nitride needles are not found in the areas showing the highest concentration of nitrogen but are located near the breaking off point of the case. The nitrogen in the concentrated area appears as patches of pearlite.

6. The depth of case measures about the same in each of these samples, that is from 0.008 to .010 inch deep. A longer time at tem-

4. Article in *Stahl & Eisen*. Vol. 25, Page 1195, by H. Braune.

CASE HARDENED SPECIMENS
S. A. E. 1015 Steel (A)

Fig. 4—Case structure on impact specimens double heat treated after carburizing. X 500. Fig. 5—Core structure on impact specimens double heat treated after carburizing. X 500. Fig. 6—Core structure on specimen quenched from pot, then single quenched for case. X 500. Fig. 7—Case structure on impact specimen single heated after carburizing. X 500. Fig. 8—Core structure on impact specimen single treated after carburizing. X 500.

perature therefore does not increase the total depth of penetration but does produce a greater concentration of carbon and nitrogen near the outside surface.

A sample of 3/8-inch screw stock was immersed in a sodium cyanide bath at 1500 degrees Fahr. for 100 hours and cooled in lime. A small section of the sample was hardened and fractured, the depth of case measuring about 0.070 inch. The total case on the unhardened specimen was sampled, the analysis of the same being as follows:

Carbon	.40%
Combined Nitrogen	.129%

The micrograph of this sample shows a few nitride needles present and the breaking up of the pearlite.

Part II

Izod Notched Bar Tests

Prior to the World War, very few laboratories in this country were equipped with machines for testing the impact value of steels. When the United States began building aviation motors however, it was found advisable to include specifications for impact values for motor parts subjected to severe stresses, such as crankshafts and connecting rods. This branch of physical testing was found to be of such great value in determining whether parts had been properly heat treated or not, that impact testing is now used in a large number of manufacturing concerns as one of the means of controlling the quality of their product.

A symposium on the subject of impact testing of materials was recently held at Atlantic City and the writer would recommend the reading of the preprint of this symposium[5] to any one interested in the subject.

As stated in the preprint, the essential results obtained from impact tests is the amount of energy absorbed by a specimen in undergoing rupture or a certain deformation. The writer has always found that steels of a brittle nature will show low impact readings and crytalline fractures, while steels possessing considerable toughness will show high impact readings with fine grained fractures. The quality of a steel should never be judged from its impact value alone, however, for it is necessary to consider the static tensile properties, torsional strength, shearing strength, etc. along with the impact reading, to properly classify the material. A plain carbon steel will usually show a higher impact reading than an alloy steel, principally due to the lower hardness of the plain carbon steel. If the plain carbon steel is heat treated so as to possess the same tensile strength as the alloy steel, however, a lower impact reading will then be obtained on the plain carbon steel than will be found on the alloy steel. One cannot estimate the impact value of a steel from its static tensile properties for the impact test is a dynamic one, while the usual tensile test is of a static nature.

As to the value of the impact test, the writer can furnish records of tests made on heat treated alloy steel forgings where the tensile properties came well within specified limits but the impact values were so low that the parts were rejected. Service tests proved that such material was unfit for the severe duty to which the parts made from the same were subjected. The

5. Symposium on Impact Testing of Materials. American Society for Testing Materials—1922 Annual meeting.

fracture obtained on the tensile test specimens in such cases would show a fine grained structure but the impact fracture possessed a fairly coarse grained structure.

An examination of the literature on the subject of case hardening shows that notched bar tests on the various types of carburizing steels have never been conducted. As such information in the writer's opinion was of sufficient value to promote research work along these lines, Izod notched bar tests, commonly known as impact tests, were conducted on the following S.A.E. steels—1015, 1112, 2315, 3115 and 6120. Two bars of each grade of steel were used for these tests, one of the bars of each type of steel being received from a different source of supply than the other bar. The analysis of these bars of steel are shown in Table II.

The specimens were completely machined before treating, both because of the difficulty we would have experienced in grinding the notch and also because the carburizing of the completely machined test piece left the specimen in a state nearer to that of an actual carburized part. The compound used for carburizing the specimens was in a finely powdered state and and contained the following materials.

Sole Leather	25%
Barium Carbonate	25%
Hard Wood Charcoal	50%

A mixture of this type gives a higher carbon content at lower temperatures than the usual run of case hardening materials and is therefore particularly adapted for parts which must be carburized at low temperatures (1500-1600

Table II
Analysis of Steels Used for Izod Tests

	Chemical Composition in Per Cent							
Type of Steel	*Carbon*	*Mang.*	*Phos.*	*Sulphur*	*Silicon*	*Chrom.*	*Nickel*	*Vanadium*
S.A.E. 1015 (A)	.19	.42	.009	.036	.01	...	...	...
S.A.E. 1015 (S)	.20	.49	.011	.026	.01	...	...	...
S.A.E. 1112 (B)	.11	.75	.133	.088	..	...	...	...
S.A.E. 1112 (P)	.11	.67	.106	.085	..	...	...	...
S.A.E. 2315 (H)	.18	.61	.013	.041	.19	...	3.35	...
S.A.E. 2315 (N)	.18	.61	.017	.031	.10	...	3.52	...
S.A.E. 6120 (M)	.15	.60	.008	.035	.13	.97	...	.20
S.A.E. 6120 (C)	.15	.67	.029	.030	.18	1.03	...	.23
S.A.E. 3115 (E)	.19	.61	.020	.025	.18	.62	1.14	...
S.A.E. 3120 (Z)	.23	.58	.031	.033	.07	.69	1.32	...

degrees Fahr.). The temperatures used for hardening the carburized Izod specimens are in accordance with the treatments recommended by the S.A.E. Iron and Steel Committee. Specimens carburized and single quenched were treated for the case only and not quenched from a temperature high enough to refine the core to any extent, inasmuch as such a treatment would leave the case in a slightly coarse condition. The latter practice is not as widely used as is treating for case refinement only.

Table III gives the results obtained from these notched bar tests as well as the hardness of the case and core. The depth of case was also measured on each of these specimens by examining the untreated end of each piece under the microscope. The S.A.E. 1015 steels and 1112 steels showed a case depth of from .023 to .025 inch, the alloy steels all possessing about a .030 inch case. It can thus be seen that the alloys promote carburization. It was

also interesting to note that 1015, 3115, and 3120 steels showed a large well defined network or envelope structure of cementite in the carburized state, the 1112 steels showing a slightly smaller grain size, the 2315 steels a small poorly defined network, while the 6120 steels showed practically no network structure. The photomicrographs of the case areas on the single treated specimens bring out this point to some extent.

The fractures on all of these specimens were carefully examined after

Table III

Izod Test Results

Steel	Heat treatment	Izod test in foot pounds	Case Hardness scleroscope	Core Hardness Brinell No.
S.A.E. No. 1015 (A)	Carburized and pot cooled; 1650-oil; 1440-water	2	90	157
S.A.E. No. 1015 (A)	Carburized and pot cooled; 1650-oil; 1410 water	2	90	151
S.A.E. No. 1015 (A)	Carburized and pot cooled; 1450-water	2	88	180
S.A.E. No. 1015 (A)	Carburized and oil quenched; 1650-oil; 1440-water	2	90	157
S.A.E. No. 1015 (A)	Carburized and oil quenched; 1450-water	3	..	166
S.A.E. No. 1015 (A)	Sand treated and pot cooled; 1650-oil; 1440-water	70	..	163
S.A.E. No. 1015 (A)	Sand treated and pot cooled; 1450-water	10	..	180
S.A.E. No. 1015 (A)	Sand treated and oil quenched; 1440-water	22	..	170
S.A.E. No. 1015 (S)	Carburized and pot cooled; 1650-oil; 1410-water	2	90	172
S.A.E. No. 1015 (S)	Carburized and pot cooled; 1430-water	2	91	196
S.A.E. No. 1015 (S)	Sand treated and pot cooled; 1650-oil; 1410-water	66	..	179
S.A.E. No. 1015 (S)	Sand treated and pot cooled; 1430-water	19	..	196
S.A.E. No. 1112 (B)	Carburized and pot cooled; 1650-oil; 1440-water	2	92	165
S.A.E. No. 1112 (B)	Carburized and pot cooled; 1450-water	1	91	180
S.A.E No. 1112 (P)	Sand treated and pot cooled; 1650-oil; 1410-water	29	..	153
S.A.E. No. 1112 (P)	Sand treated and pot cooled; 1430-water	8	..	167
S.A.E. No. 2315 (H)	Carburized and pot cooled; 1540-oil; 1400-oil	6	82	370
S.A.E. No. 2315 (H)	Carburized and pot cooled; 1540-oil; 1350-water	8	87	302
S.A.E. No. 2315 (H)	Carburized and pot cooled; 1370-water	3	87	329
S.A.E. No. 2315 (H)	Sand treated and pot cooled; 1540-oil; 1350-water	28	..	311
S.A.E. No. 2315 (H)	Sand treated and pot cooled; 1370-water	18	..	340
S.A.E. No. 2315 (N)	Carburized and pot cooled; 1540-oil; 1350-water	6	87	364
S.A.E. No. 2315 (N)	Carburized and pot cooled; 1370-water	2	84	387
S.A.E. No. 2315 (N)	Sand treated and pot cooled; 1540-oil; 1350-water	27	..	349

(*Table III continued on next page*)

Table III (Continued)
Izod Test Results

Steel	Heat treatment	Izod test in foot pounds	Case hardness scleroscope	Core hardness Brinell No.
S.A.E. No. 6120 (M)	Carburized and pot cooled; 1650-oil; 1475-water	10	92	265
S.A.E. No. 6120 (M)	Carburized and pot cooled; 1500-water	2	92	255
S.A.E. No. 6120 (M)	Sand treated and pot cooled; 1650-oil; 1475-water	37	..	265
S.A.E. No. 6120 (M)	Sand treated and pot cooled; 1500-water	23	..	252
S.A.E. No. 6120 (C)	Carburized and pot cooled; 1650-oil; 1475 water	11	92	295
S.A.E. No. 6120 (C)	Carburized and pot cooled; 1500-water	4	92	295
S.A.E. No. 3115 (E)	Carburized and pot cooled; 1575-oil; 1425-water	4	91	295
S.A.E. No. 3115 (E)	Carburized and pot cooled; 1440-water	2	92	349
S.A.E. No. 3115 (E)	Sand treated and pot cooled; 1575-oil; 1425-water	20	..	311
S.A.E. No. 3115 (E)	Sand treated and pot cooled; 1440-water	8	..	321
S.A.E. No. 3120 (Z)	Carburized and pot cooled; 1525-oil; 1425-water	2	91	477

Table III Notes

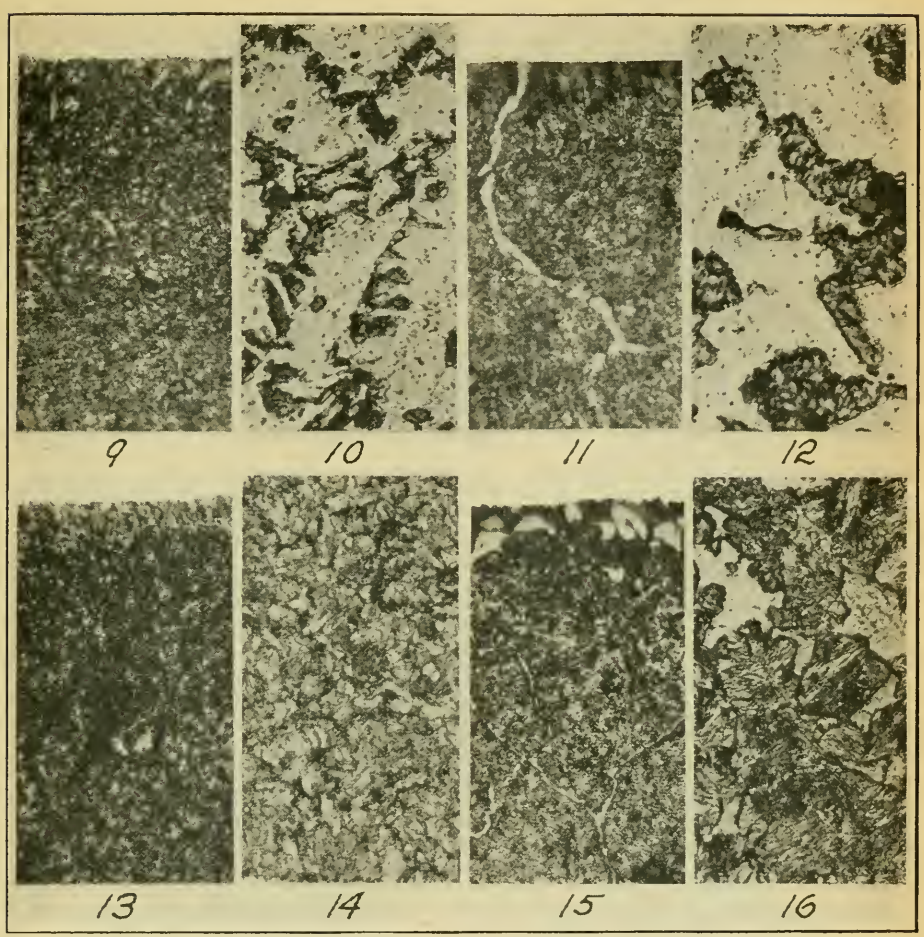
1—Temperatures are given in degrees Fahrenheit.
2—Samples were carburized by heating in a finely powdered form of case hardening compound for four hours at 1650 degrees Fahr.
3—Samples were sand treated by heating in sand for four hours at 1650 degrees Fahr.
4—Lead bath furnace used for treating the carburized specimens.
5—All samples drown to 350 degrees Fahr. before testing.
6—Izod results represent the average of from three to six tests in every case.

being tested, the results being shown in table IV. From these fracture tests, it can be seen that all of the alloy steels possess a fine grained case and core after carburizing and double quenching, but show a crystalline core, with a fine grained case after carburizing and single quenching. The carburized 1015 steels show a slightly coarse grained case and coarse grained core after double treating, but after single quenching show a slightly coarse grained case with a very coarse core. The sand treated specimens of 1015 steel show a fine grained fracture after double quenching but a very coarse grained fracture after single quenching, and also after sand treating, quenching from pot, and single quenching.

The carburized samples of Bessemer screw stock (1112 steel) possess a coarse grained case and a very coarse grained core after double quenching as well as after single quenching. The specimens of 1112 steel that were sand treated also show a very coarse grained fracture both after double and single quenching. It can thus be seen that screw stock can not be refined by double quenching as can the other types of case hardening steels. Referring again to Table II, we obtain the following information as to impact values and hardness tests—

Izod Tests

The S.A.E. 1015 steels gave the highest impact readings of all the



CASE HARDENED SPECIMENS

S. A. E. 1112 Steel (B)

Fig. 9—Case structure on impact specimen double heat treated after carburizing. X 500. Fig. 10—Core structure on impact specimen, double heat treated after carburizing. X 500. Fig. 11—Case structure on impact specimen, single heat treated after carburizing. X 500. Fig. 12—Core structure on impact specimen, single heat treated after carburizing. X 500.

S. A. E. 3115 Steel (E)

Fig. 13—Case structure on impact specimen double heat treated after carburizing. X 500. Fig. 14—Core structure on impact specimen double heat treated after carburizing. X 500. Fig. 15—Case structure on impact specimen single heat treated after carburizing. X 500. Fig. 16—Core structure on impact specimen single heat treated after carburizing. X 500.

steels tested, when sand treated and double quenched. The high results obtained from this type of steel are due we believe to the softness of the material. This type of steel however does not show as high static tensile properties as do the alloy case hardening steels in the double treated condition. The high impact reading on the 1015 steels therefore is obtained at the sacrifice of its tensile strength. The 1112 steel, or Bessemer screw stock, showed an impact value of less than half that obtained on the 1015 steels, due to the high percentage of impurities present. The alloy steels showing the highest Izod readings when sand treated and double quenched were those of

the 6120 series the 2315 steel coming second, the S.A.E. 3115 steels showing the lowest impact readings. These 3 types of alloy case hardening steels all possess about the same static tensile properties if the carbon is approximately the same in each case.

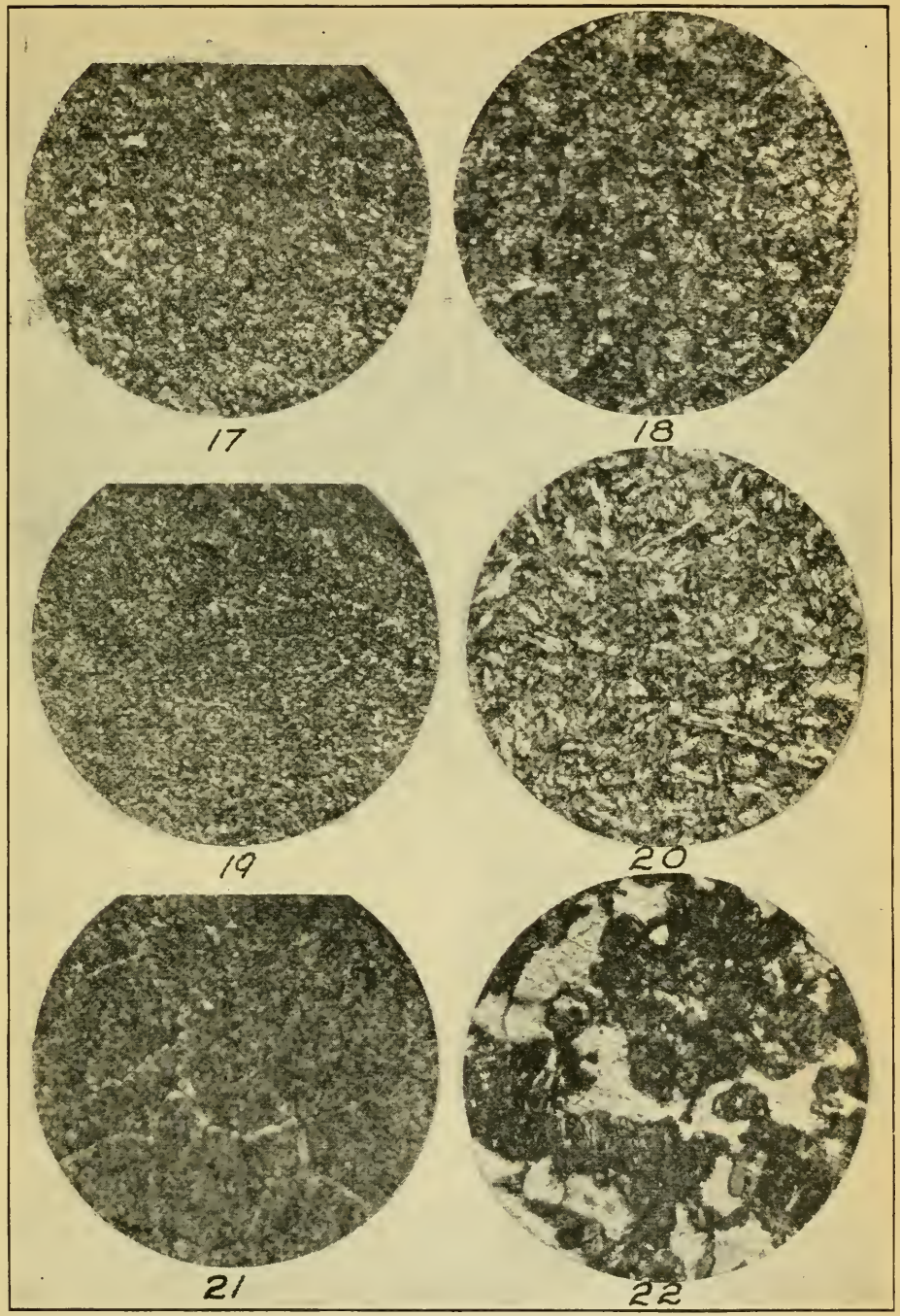
The values obtained on the different types of steels, sand treated and single quenched, were all considerably lower than those found on the specimens double treated. The 6120 steel gave the highest Izod reading in the

Table IV
Fractures on Izod Test Specimens

Steel	Treatment	Case refinement Grained structure	Core refinement Grained structure
S.A.E. 1015	Carburized and double quenched.	Slightly coarse	Coarse
S.A.E. 1015	Carburized and single quenched..	Slightly coarse	Very coarse
S.A.E. 1015	Sand treated and double quenched		Fine
S.A.E. 1015	Sand treated and single quenched		Very coarse
S.A.E. 1015	Sand treated, pot quenched, single quenched		Very coarse
S.A.E. 1112	Carburized and double quenched.	Coarse	Very coarse
S.A.E. 1112	Carburized and single quenched..	Coarse	Very coarse
S.A.E. 1112	Sand treated and double quenched		Very coarse
S.A.E. 1112	Sand treated and single quenched		Very coarse
S.A.E. 3115	Carburized and double quenched.	Fine	Fairly fine
S.A.E. 3115	Carburized and single quenched..	Fine but crystalline outer rim	Coarse
S.A.E. 3115	Sand treated and double quenched		Fairly fine
S.A.E. 3115	Sand treated and single quenched		Coarse
S.A.E. 2315	Carburized and double quenched.	Very fine	Fine
S.A.E. 2315	Carburized and single quenched..	Very fine but crystalline outer rim	Slightly coarse
S.A.E. 2315	Sand treated and double quenched		Fine
S.A.E. 2315	Sand treated and single quenched		Slightly coarse
S.A.E. 6120	Carburized and double quenched.	Fine velvety	Fine
S.A.E. 6120	Carburized and single quenched..	Fine	Coarse
S.A.E. 6120	Sand treated and double quenched		Fine
S.A.E. 6120	Sand treated and single quenched		Coarse

single treated condition, the other steels running as follows, from highest to lowest, 2315, 1015, 3115 and 1112.

The specimens of 1015 steel sand treated, quenched from the pot into oil and then single quenched showed only about 1/3 the strength of specimens sand treated, pot cooled and double quenched. A very coarse grained fracture was obtained on those samples that were pot quenched, for a long soaking above the critical temperature before quenching produces a coarse grained structure. Material given this treatment however possesses a slightly finer grained structure and higher Izod value than specimens pot cooled, then single quenched. One would expect the S.A.E 1015 steels, which showed such high impact readings in the sand treated condition, to show correspondingly high values when carburized and hardened for case and core refinement. We found however that these plain carbon steels showed a very low impact reading when carburized and double quenched (2 foot pounds) probably due to the brittleness of the case, as compared with the alloy steel cases. The core also showed a coarse grained structure as compared with the fine grained fracture obtained on the 1015 steel specimens that were sand treated and double quenched. The same Izod readings were obtained on the 1015 steel specimens single treated after carburizing as were found on the double treated carburized specimens, but the core was much coarser on the pieces

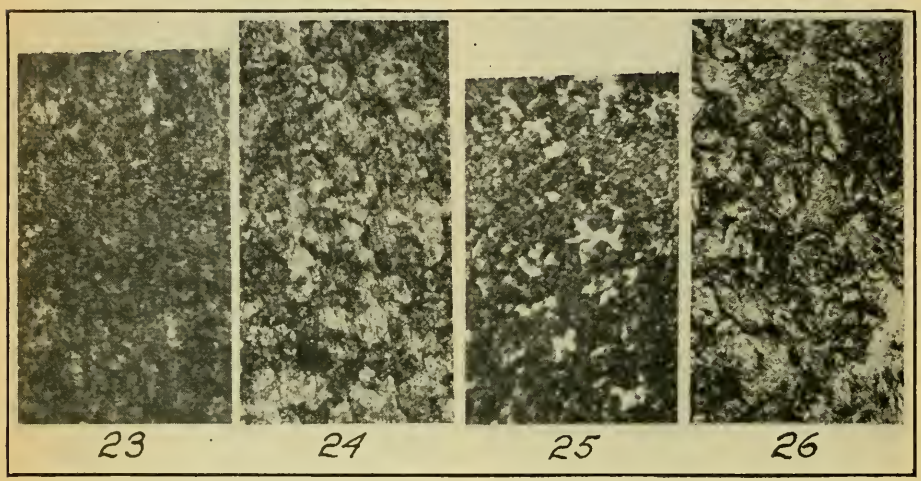


S. A. E. 2315 Steel (H)

Fig. 17—Case structure on impact specimen double quenched after carburizing, second quench being in oil. X 500. Fig. 18—Core structure on impact specimen double quenched after carburizing, second quench being in oil. X 500. Fig. 19—Case structure on impact specimen double quenched after carburizing, second quench being in water. X 500. Fig. 20—Core structure on impact specimen double quenched after carburizing, second quench being in water. X 500. Fig. 21—Case structure on impact specimen single quenched after carburizing. X 500. Fig. 22—Core structure on impact specimen single quenched after carburizing. X 500.

that were quenched for case refinement only. Quenching from the pot, then double and single treating also gave readings of from 2 to 3 foot pounds.

The S.A.E. 6120 steels in the carburized and double treated state gave the highest impact readings of any of the steels tested, the 2315 steels showing slightly lower values. As in the case of the sand treated specimens, the 3115 steel gave the lowest values in the carburized and double treated conditions of any of the alloy steels tested. The 3120 steel gave lower readings than the 3115 samples due to the greater core hardness produced by the higher carbon content of the 3120 steel. The 1015 and 1112 steels gave the



CASE HARDENED SPECIMENS
S. A. E. 6120 Steel (M)

Fig. 23—Case structure on impact specimen double heat treated after carburizing. X 500. Fig. 24—Core structure on impact specimen double heat treated after carburizing. X 500. Fig. 25—Core structure on impact specimen single heat treated after carburizing. X 500. Fig. 26—Core structure on impact specimen single heat treated after carburizing. X 500.

same low readings in the carburized and double quenched condition as was obtained by the 3120 steel specimens. As was the case in the sand treated specimens, the alloy steels single quenched after carburizing, showed lower Izod readings than when quenched for both core and case.

It may be interesting to note that in a test run some time ago by one of the large automobile concerns in Detroit, the following oil hardening gear steels, tested for impact values, came out as follows, from highest to lowest: 6150, 2350, 3250 and 3150. It is claimed by a well known authority on physical testing, that impact strength drops off very rapidly with a drop in temperature. One would thus expect a greater failure of parts subjected to shock when exposed to cold weather.

Hardness Tests

The Brinell hardness tests on the core of the plain carbon steels showed much lower readings than the values obtained on the alloy steels. With the exception of the 6120 steels, all of the specimens from the different types of steels, single quenched after carburizing or sand treating, showed higher Brinell readings than samples double treated after carburizing. It is also interesting to note the effect of 4 points difference in carbon on the hardness of the core of the chrome-nickel series. As a similar relation is to be expected from a variation in carbon on the 2315 and 6120 steels, one can thus see the necessity of obtaining material within a close carbon range if the sections

to be carburized are small and toughness is an important factor.

The case scleroscope readings showed about the same on all of the samples, with the exception of the 2315 series, where slightly lower readings were obtained. These 3½ per cent nickel steel specimens were also the only ones that were not file hard to the Nicholson flat temper testing file, when in the carburized and hardened state.

Photomicrographs

Figs. 4 through 26 show photomicrographs of the case and core of the different types of steel after carburizing and double treating as well as after single quenching for case refinement only. The case on all of the steels after double quenching show a fairly fine grained martensitic structure, with ce-

Table V
Static Tension Tests

Steel	Heat treatment	Tensile strength in pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent	Brinell hardness
S.A.E. 1015	Heated in sand for 4 hours at 1650 degrees Fahr. and cooled in pot. Reheated to 1650 degrees Fahr. and oil quenched. Reheated to 1400 degrees Fahr. and water quenched....	103,100	11.5	26.5	192
S.A.E. 1015	Sand treated as above. Reheated to 1450 degrees Fahr and water quenched	127,500	4.8	5.5	223
S.A.E. 6120	Sand treated as above. Reheated to 1650 degrees Fahr. and oil quenched. Reheated to 1450 degrees Fahr. and water quenched	125,500	17.0	35.4	241
S.A.E. 6120	Sand treated as above. Reheated to 1490 degrees Fahr. and water quenched...	137,800	13.1	30.0	255

Analysis of Steels Used for Above Tests

	S.A.E. 1015 Per cent	S.A.E. 6120 Per cent
Carbon	.18	.14
Manganese	.31	.68
Phosphorus	.021	.008
Sulphur	.041	.024
Chromium	..	1.03
Vanadium	..	.15

mentie in the globular form and well distributed throughout the section. A trace of the network structure of cementite is found however in the case areas of specimens single quenched after carburizing, for the temperature used for refining the case only was not high enough to entirely break up the coarse grained structure produced in the carburizing operation. The 6120 steels are the exception to the above for practically no network was present after carburizing and before hardening. This network of cementite is quite often the cause of grinding cracks and spalling of the case, so it is highly desirable to break up this network structure by properly carburizing and hardening the steel. Quenching from the pot and single quenching, while not refining the grain as well as double treating after carburizing, does have

the advantage of preventing the formation of this coarse grained network structure of cementite.

The core structures on all of the impact specimens, double quenched after carburizing, show a much finer grain than when single quenched, with the exception of the samples of Bessemer screw stock or 1112 steel, which showed a large coarse grained structure both after double and single quenching.

Tensile Tests

Static tension tests were conducted on specimens made of 1015 and 6120 steels, sand treated, then double and single quenched. The results given in Table V indicate that the higher tensile strengths obtained on specimens single quenched after carburizing are gained at the expense of the ductility of the material, especially in the case of the 1015 steel. The fractures obtained on the specimens of 1015 steel in the double treated state showed a fine grained structure but the specimens single quenched showed a very coarse grained fracture. Not so much difference was noted in the fractures of the 6120 steel specimens after double and single quenching, only a slight coarsely grained structure but the specimens single quenched showed a very coarse grained single treating being obtained on the specimens of this type of steel after single treating.

In conclusion, the writer trusts that this paper may arouse sufficient discussion to result in the publication of several more articles along similar lines, for such information should be of considerable value to all interested in the subject of case hardening.

LATHE BREAKDOWN TESTS OF SOME MODERN HIGH SPEED TOOL STEELS

By H. J. French and Jerome Strauss

Technical Abstract

This report is concerned with comparisons of performance of modern high speed tool steels in so-called "lathe breakdown tests," in which the endurance of tools is measured under definite working conditions, and likewise with the limitations of this method when applied to the purchase of steel. The modern steels are first classified according to chemical composition and this division made use of in discussion of results obtained.

Important features developed or conclusions drawn may be summarized as follows:

1. *Breakdown tests are not satisfactory as the basis of purchase for high speed tool steels.*
2. *While competitive comparisons of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty providing suffient tools are tested and averages of at least 2 grinds are used in the interpretation of results.*
3. *In certain severe breakdown tests with roughing tools on 3 per cent nickel steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low-tungsten high-vanadium and cobalt steel was superior to that of the high-tungsten low-vanadium type and special steel containing about 1/4 per cent uranium or 3/4 per cent molybdenum. The average power consumption in all cases was practically the same so that this factor need not be introduced in comparisons which may be made on the basis of endurance of the tools.*
4. *Modification in test conditions including small changes in tool angles but principally changes in cutting speed more markedly affected the performance of steel containing cobalt or special elements such as uranium or molybdenum than that of the basic types (plain chromium-tungsten-vanadium steels).*
5. *The relatively poor endurance of the high tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than either the low or high tungsten steels.*
6. *Hardness determinations and examination of fractures*

A paper to be presented before the Detroit Convention October 2-7. The authors H. J. French is physicist, United States Bureau of Standards and Jerome Strauss, is chief chemist, United States Naval Gun Factory.

indicate that the various types of commercial high speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions, and might counterbalance slight advantages in performance.

Introduction

UNLIKE structural steels, which are generally sold within definite limits of chemical composition, most carbon and practically all alloy tool steels are supplied as brands or under trade names. There are some advantages to this system, both from the standpoint of manufacturer and purchaser, but it has seriously retarded general dissemination of knowledge concerning different types and in many instances has been responsible for erroneous impressions regarding their properties and applications. This applies generally to tool steels but in particular to that important class termed "rapid" of "high speed" steels with which the authors are alone concerned in this report.

It has long been recognized that high grade raw materials, good melting practice and great care in fabrication, all based on an intimate knowledge of the product, are necessary in the manufacture of high speed tool steels and that variations in the many operations involved, which are closely related to tool performance, may readily overshadow the effects of small differences in chemical composition. However, this condition has frequently been misrepresented with the result that the importance of chemical requirements has been largely disregarded by purchasers.

In quite a few instances large consumers have selected brands on the basis of performance in so-called "breakdown tests" in which the endurance of tools is measured under fixed working conditions though the selling price and power consumption of the various steels may be introduced in any comparisons which are made. In recent years tests of this type have also been used in comparing the performance of special steels or in determining the effects of variations in heat treatment, despite the fact that Taylor[1] specifically recommended determining the cutting speed which would produce failure in 20 minutes under otherwise fixed working conditions and described at great length the reasons for following such a procedure. Comparison of the breakdown and Taylor tests is not within the scope of this report. The former is accepted because it has found commercial application and a portion of the work described in subsequent paragraphs may be characterized as a critical survey of this method of test. The cutting speeds, feed, depth of cut and general test conditions approximated those used in a number of cases for the purchase of large quantities of steel.

In studying the results first obtained, marked superiority in performance of certain types of steel was observed so that these alloys are first grouped according to chemical composition and the resulting classification is used in discussion of results of the lathe cutting tests. It is based upon the analysis of about 65 lots representing nearly 40 brands produced throughout the period 1919-1922[2].

Five sets of breakdown tests are described. The first three, which were

1. F. W. Taylor: On the Art of Cutting Metals. *Trans.* A. S. M. E., 1906.

2. Approximately ⅓ of all analyses was made by H. Bright, Assoc. Chemist, Bureau of Standards, ⅓ by chemists associated with one of the authors and the remainder collected from various other sources.

carried out at high speed with heavy cut and feed, cover comparisons of about 25 brands and are presented to show some of the limitations in test methods which have been used in the purchase of high speed tool steels. Test series No. 4 was carried out with reduced feed in order to ascertain whether the superior endurance observed for certain groups in the first three sets of tests was maintained under more moderate working conditions in which lower frictional temperatures were produced.

The expense of large tool tests, time, labor and special equipment required, made it desirable to carry out test No. 5 to determine whether comparable results could be obtained with small tools. Results of fracture tests, miscroscopic examination and secondary hardness determinations are also included to throw light upon the quality of metal tested or the characteristics of the various steels under heat treatment.

Previous Investigations

No attempt will be made to review the very large number of publications which have appeared since the discovery of the unique and remarkable properties of high speed tool steels and the presentation of a report by Taylor and White[3] which has since been characterized as the most important single metallurgical contribution made in the United States. Much of this more recent information does not have a very direct bearing upon the phases which will be considered while results of cutting tests of different brands or steels which have appeared from time to time either do not represent the best of the current types or are not strictly comparable on account of differences in material cut, angles, shape and size of tools, etc. Such data as may be introduced to advantage will be referred to in connection with the several features emphasized in subsequent paragraphs but no selected list of references is appended as a fairly complete bibliography on high speed tool steels has been prepared by one of the Engineering Libraries for the National Research Council and is now in preparation for publication.

Classification of Modern High Speed Tool Steels

While the essential alloying elements in high speed tool steels are chromium and tungsten practically all brands now produced in this country for roughing tools contain between 0.5 to 2.25 per cent vanadium. The term *modern* high speed tool steels therefore refers to chromium-tungsten-vanadium steels (which may or may not contain additional special elements) and little or no attention will be paid to the very few brands still manufactured without the intentional addition of vanadium, particularly as they are inferior in performance to the former types.

The modern steels may be grouped under 5 headings, as follows:

1. Low tungsten steels
2. Medium tungsten steels
3. High tungsten-low vanadium steels
4. Cobalt steels
5. Steels containing one or more special elements such as molybdenum or uranium and called "special steels"

Their relative importance from the standpoint of number of brands within each group and limits of chemical composition are indicated in Tables I, II and III which are based on results of analysis of one or more lots of 39 brands.

3. F. W. Taylor: On the Art of Cutting Metals. *Trans.* A. S. M. E., 1906.

Table I

Summary of Composition of 39 Brands of Modern High Speed Tool Steels Based on Analysis of 66 Lots

Type of High Speed Tool Steel	No. of lots analyzed	No. of brands found in specified type	Carbon, per cent			Chromium, per cent			Tungsten, per cent			Vanadium, per cent			Cobalt, per cent			Mo, Per cent	U, Per cent
			Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.		
1. Low tungsten—high vanadium	10	6	.56	.74	.65	2.21	4.45	3.69	11.10	14.00	13.07	.50	2.15	1.47	...	...	...	...	..
2. Medium tungsten	4	2	.62	.71	.66	3.01	4.67	3.93	14.08	15.79	14.92	.69	2.07	1.54	...	...	...	...	..
3. High tungsten—low vanadium	36	22	.45	.85	.66	2.26	4.70	3.54	16.13	19.65	17.90	.48	1.24	.88	...	...	...	...	..
4. Cobalt	8	7	.58	.88	.69	2.78	4.31	3.70	13.07	18.79	16.38	.91	1.63	1.21	1.86	4.73	3.28	...	..
5. Special	8	7	..	..	..						(Typical	Compositions)							
(a) Molybdenum steels	..	..	..	..	.69	...	...	3.52	....	....	12.88	..	...	1.97	...	...	...	.71	..
	..	..	..	..	.64	...	...	3.58	....	....	16.65	..	...	1.10	...	...	...	.71	..
	..	..	..	..	.60	...	...	4.00	....	....	15.50	..	...	1.20	...	...	...	.50	..
(b) Cobalt-molybdenum steels	..	..	..	..	.65	...	...	4.25	....	....	17.70	..	...	1.00	...	...	4.88	1.07	..
(c) Uranium steels	..	..	..	..	.66	...	...	3.94	....	....	13.80	..	...	1.45	...	...	...	...	.23
	..	..	..	..	.58	...	...	3.85	....	....	13.64	..	...	1.36	...	...	...	...	.19
	..	..	..	..	.64	...	...	3.21	....	....	17.03	..	...	.86	...	...	...	...	.26
	..	..	..	..	.80	...	...	3.63	....	....	19.80	..	...	.80	...	...	...	...	.21
Totals	66	44	..	..	..	...	...	...	....	....	....	..	...	...	...	...	...	...	..

About half of these are of the third type or so-called high tungsten-low vanadium steels. The low tungsten type, cobalt steels and those containing special elements such as molybdenum or uranium are about equally represented but, together, do not exceed the number of high tungsten steels. A medium tungsten-low vanadium steel is regularly manufactured in England[1]

Table II

Proportions of Manganese, Phosphorus, Sulphur and Silicon Found in 66 Lots of Modern High Speed Tool Steels Representing 39 Brands

Type of High Speed Tool Steel	Manganese per cent			Phosphorus per cent			Sulphur per cent			Silicon per cent		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
All types.	.09	.43	.26	.004	.051	.023	.009	.061	.027	.09	.81*	.27

*Only one lot contained more than 0.51 per cent silicon.

Table III

Chemical Compositions of Cobalt High Speed Tool Steels (Produced in the United States)

Class of Steel	Brand	—Chemical Composition— C	Cr	W	V	Co	——Per cent—— Mn	P	S	Si
(a) Low tungsten—low cobalt..	A	.68	3.96	13.07	1.63	1.86	.19	.018	.021	.37
(b) Low tungsten—high cobalt..	B	.67	3.72	13.50	1.28	4.23	.42	.023	.023	.39
	B	.76	3.41	14.01	1.60	4.73	.34	.029	.061	.27
(c) High tungsten—low cobalt..	C	.66	3.45	17.80	1.06	2.54	.20	.022	.019	.45
	D	.88	4.29	18.79	1.30	2.92	..	...	...	.10
(d) High tungsten—high cobalt..	E	.58	2.78	17.56	.93	3.35	.09	.016	.026	.18
	E	.72	3.26	18.40	.86	3.10	.08	.020	.017	.11
	F	.59	4.31	18.58	.91	3.34	.17	.024	.016	.10
	G	.68	3.68	17.51	.97	3.27	.30	.014	.010	.22

Table IV

Proportions of Carbon Found in 66 Lots of Modern High Speed Tool Steels Representing 39 Brands

Carbon range*	No. of steels in given limits	Proportion of total number of steels in given limits	
0.45 to 0.50	1	1.5	
0.50 to 0.55	1	1.5	
0.55 to 0.60	6	9.1	
0.60 to 0.65	22	33.3	86.3
0.65 to 0.70	22	33.3	
0.70 to 0.75	7	10.6	
0.75 and over	7	10.6	
	66	99.9	

* Minimum value observed 0.45 per cent carbon.
* Maximum value observed 0.88 per cent carbon.

but evidently a similar product is of minor importance in the United States as only two examples were found in the samples analyzed and one of these contained high vanadium which is characteristic of a low tungsten steel. In addition, different lots of both brands were found within the limits of classes 1 or 3 (Table I) so that the medium tungsten steels may be considered largely as "off-heats" and the least important of the first three groups comprising "basic types".

1. T. H. Nelson: Comparison of American and English Methods of Producing High Grade Crucible Steels. *Raw Material*, 1, No. 12, p. 421.

Compositions of Various Types

There is no marked difference in the proportions of carbon, manganese silicon or chromium found in the different groups. In fact the average values for carbon and chromium shown in Table I are very nearly the same and much closer than might ordinarily be expected from any such survey as the one under consideration. The principal differences are, therefore, in the pro-

Table V

Proportions of Chromium Found in 66 Lots of Modern High Speed Tool Steels Representing 39 Brands

Proportions of Chromium* per cent	No. of steels in given limits	Proportion of total number of steels in given limits, per cent		
2.00 to 2.50	2	3.0		
2.50 to 3.00	3	4.5		
3.00 to 3.50	18	27.3		
3.50 to 4.00	25	37.9	—65.2	86.4
4.00 to 4.50	14	21.2		
4.50 to 5.00	4	6.1		
	66	100.0		

* Minimum value observed 2.21 per cent Cr.
* Maximum value observed 4.70 per cent Cr.

portions of tungsten and vanadium present and whether cobalt or some such special elements as molybdenum or uranium have been introduced.

The three basic types, referred to previously as the low tungsten, medium tungsten and high tungsten varieties, are often called respectively 13, 15 and 18 per cent tungsten steels and examination of Table I will show that these values are practically identical with the averages obtained in the present survey. The best known brands of the first type contain about 1.75 to 2.25 per cent of vanadium but there appears to be a second group in which lower proportions of this element, between about 0.75 and 1.25 per cent, are found. The so-called 18 per cent tungsten steels usually contain about 0.50 to 1.25 per cent vanadium.

The alloys of group 4, which are regularly produced by a number of manufacturers and therefore not included in the special steels of group 5 may be subdivided into the following:

a. Low tungsten-low cobalt steels
b. Low tungsten-high cobalt steels
c. High tungsten-low cobalt steels
d. High tungsten-high cobalt steels

It is to be noted that these steels fall naturally into groups representing basic types to which varying proportions of cobalt, between about 2 and 5 per cent, have been added. However, the vanadium is generally found to be near the average values or low limits shown in Table I. A similar subdivision can be made for the special steels (Table I) containing either molybdenum or uranium but since, for the most part, they are not yet of very great industrial importance and can in some cases at least be characterized as experimental heats, no additional comments concerning their compositions need be added.

The average carbon content of all major groups is between 0.65 and 0.70

per cent but variations ordinarily encountered are between 0.55 and 0.75 per cent. At times even higher proportions of carbon are found but there is a decided tendency to keep this element above the specified low limit (0.55 per cent) as shown in Table IV.

There appears to be a general tendency on the part of most manufacturers to keep the manganese content of all steels below about 0.25 per cent but larger proportions are frequently found. This element, and carbon also, tend to increase the hardness of high speed tool steels but at the same time they make the tools more brittle. It was for this reason that Taylor recommended the manganese content be limited to about 0.15 per cent.

With respect to the effect of silicon in high speed tool steels Taylor reported:—"The statement has been published several times that high silicon tended toward higher cutting speeds in high speed tools. In developing our patent, we experimented quite thoroughly with this element and arrived at the conclusion that high silicon tended toward slower cutting speeds, particularly when cutting the harder metals. In our patent, therefore, we recommended the low silicon, 0.15 per cent".

It is interesting to note that the average silicon content found in 66 lots of the modern steels is almost twice the value specified and that a fair maximum for this element would be about 0.45 per cent although one brand contained as much as 0.8 per cent.

The high limits of phosphorus and sulphur are somewhat greater in these alloys than those ordinarily specified for structural steels and considerably in excess of proportions usually present in tool steels other than high speed. Taylor found that high phosphorus and sulphur "were much less injurious to high speed tools than they were to carbon tools" but claimed they still exerted a harmful influence and because of the high cost of production for the former, resulting from necessarily large additions of expensive alloying elements, recommended that only irons low in phosphorus and sulphur be used in their manufacture. The present general tendency, as regards chemical composition, seems to include an increase in the permissible proportions of those elements, which may be termed impurities, over amounts originally recommended by Taylor. However, certain brands will repeatedly contain higher proportions of manganese, silicon, phosphorus or sulphur than others of the same type, a natural result of differences in raw materials and mill practice.

As previously stated, no marked differences in chromium are observed between different groups. More than half of all samples analyzed contain between 3 and 4 per cent while the proportions present in over 85 per cent of these steels is between 3 and 4.5 per cent (Table V). There are, of course, variations outside the specified limits and certain brands may be considered to contain somewhat higher or lower chromium than others but the majority of steels are within fairly close limits with respect to this element. The chromium in the modern steels is also lower than that in the best of Taylor's steels and in this respect both English and American products are similar. However, the latter contain generally higher vanadium as is shown in Table VI.

The observed uniformity in chemical composition of steels containing large proportions of special elements is worthy of attention as is also the fact that so many brands produced under widely different manufacturing conditions fall into such few groups. This condition must be considered as recognition of the importance of the chemical composition of high speed tool steels,

not alone as a single class within general limits, but from the standpoint of the different types in this class. It is therefore patent to examine the results of cutting tests of modern steels with the view of comparing types as well as brands and both methods will be used in interpretation of the test

Table

Compositions of American and (Cobalt and Special

Type of Steel	Commonly called	Produced in	Carbon	Manganese
Low tungsten	13% Tungsten steel	United States	.60/.75	.10/.45
	"Twist Drill"	England*	.50/.70	.20 max.
Medium tungsten	15% Tungsten steel	United States	.60/.75	.10/.45
	"Standard"	England*	.55/.65	.20 max.
High tungsten	18% Tungsten steel	United States	.55/.75	.10/.45
	"Super"	England*	.55/.65	.20 max.

*These limits obtained from T. H. Nelson: Comparison of American and English Methods of Producing
†Sometimes up to 20 per cent.

data which follow. It might be well, at this point, to call attention to the fact that metallurgists have often taken exception to the classification of commercial high speed tool steels according to chemical composition, particularly when the tungsten content is made the basis of division. This is because the combined effects of small variations in the other elements present and differences in methods of production or treatment might affect the performance to as great a degree as changes in the proportions of tungsten. Despite such variations the majority of steels tested showed performance generally characteristic of the group in which they were placed so that the chemical classification made and its application to discussion of the cutting tests appears justifiable.

Severe Breakdown Tests of 1″ x ½″ Roughing Type of Lathe Tool

Description of Tests

In tables XI and XII are given results of three series of cutting tests made with 1 x ½-inch lathe tools prepared from about 25 brands and these are grouped according to the type compositions previously described. The first two were carried out in different shops with slightly different tool angles and cutting speeds as shown in Table VII but with tools made from the same bars of any single brand. Heat treatments used in both series were carried out at one time with the same equipment and operators under the instructions of the manufacturers' representatives.

The third set of tests consisted of some of the tools in the first series after they had been thoroughly annealed, re-treated and ground, together with tools from different lots of the same brands or types not originally represented. Annealing was carried out by heating to 1550 degrees Fahr. and slowly cooling in a furnace to room temperature while the final heat treatments were not necessarily those recommended by the manufacturer but were chosen with the idea of obtaining the best tool performance for each type. These treatments were carried out by different operators in two shops which had not participated in tests Nos. 1 and 2. Thus the three sets of tests should furnish a definite idea regarding the possibility of reproducing results in a severe breakdown test with roughing tools, particularly with respect to brand or type comparisons.

Tool Form

The form of tool selected for all tests was that known as Sellers No. 30

and is commonly employed for heavy duty roughing work. Its angles are 6-degree clearance, 8-degree back slope and 14-degree side slope, while the radius of the nose was made 3/16 inch. The edge of the tool between this arc and its full width was straight and met the surface of the bar about 1 inch

VI
English High Speed Tool Steels.
Steels not included.)

Usual Limits of Chemical Composition Per Cent					
Phosphorus	Sulphur	Silicon	Chromium	Tungsten	Vanadium
Max. .050	Max. .060	.10/.45	3.25/4.25	11.00/14.00	1.75/2.25 or .50/1.25
low as possible		trace	2.50/3.00	12.00/14.00	Nil to trace
Max. .050	Max. .060	.10/.45	3.25/4.50	14.00/16.00	.50/2.25
low as possible		trace	2.75/3.50	14.00/16.00	Nil to .50
Max. .050	Max. .060	.10/.45	3.00/4.50	16.00/19.50†	.50/1.25
low as possible		trace	3.00/4.00	16.00/18.00†	.50/1.00

High Grade Crucible Steels. Raw Material, 4, No. 12, p. 424.

from the end. This form was adhered to in tests Nos. 2 and 3 but in test No. 1 the angles were accidently modified to 6-degree clearance, 7½-degree back slope and 12-degree side slope.

Heat Treatment

After grinding roughly to the described form the tools were warmed on top or in front of the preheating furnace to about 300 degrees Fahr. preheated in semi-muffle or muffle type furnaces, subsequently heated to the quenching temperature and quenched in either sperm or Houghton's No. 2 soluble quenching oil. They were then tempered at temperatures shown in Tables XI and XII.

The tools were next carefully ground wet in an automatic machine in order thay they would all be of the same form. In addition to grinding the nose, top and bottom surfaces were ground on those tools tested in the third series. This was made necessary on account of slight distortion which resulted from hardening the entire length so that both ends of each bar could be tested, instead of heating only one end as was the case with tools used in tests Nos. 1 and 2. High heat furnace temperatures were controlled by platinum thermocouples connected to potentiometers while base metal couples and either direct reading galvanometers calibrated just prior to test or potentiometers were used in maintaining preheating and tempering temperatures. For the few tools subjected to very low-temperature tempering calibrated thermometers were used. Preheating was carried out in semi-muffle type furnaces except for a few tools used in test No. 3 when electrically heated muffles were used.

The time for which tools were held in the high heat furnace was carefully controlled in all cases. The relatively large variations and generally longer periods in test No. 3 were due principally to the use of several furnaces of varying size and construction necessitated by breakdown of the first unit. The "sweating operation" in the hardening of high speed tool steels is a most important feature and the rapidity with which the desired effect can be produced for steel of nearly constant mass depends largely on the heating units. If the steel is held too long at high temperatures in the neighborhood of or above 2400 degrees Fahr. excessive oxidation and considerable decarburization result and in addition the metal becomes "mushy" so that it readily breaks when squeezed by tongs (Fig. 1). The time for which tools were held in the high heat furnace was therefore longer in those cases in

which units of relatively small thermal capacity were employed but in making use of any furnace preliminary tests were first made to determine what was considered to be the proper time of heating.

For tests Nos. 1 and 2 oil fired semi-muffle furnaces were employed while a similar type, heated by gas, or a carbon plate resistance furnace was used in hardening tools tested in the third series.

Test Procedure

Heavy duty motor-driven engine lathes, of a capacity somewhat in excess of that actually required for the work to be performed, were used in all

Fig. 1—Partially melted tool left too long in the high heat furnace at 2415 degrees Fahr. Tool broke where held by tongs in attempting to remove it from furnace.

tests. That employed in tests Nos. 1 and 3 is shown in Fig. 2. Speed control of the motor was such as to permit obtaining the desired surface speed of the test log within about +5 and —0 per cent and all tests were run dry.

Table VII
Conditions Under Which 1 x ½-inch Lathe Tools Were Tested

Test Series	1	2	3
Desired cutting speed, feet per minute at bottom of cut	67	61	60
Feed, inches per rev	.045	.045	.045
Depth of cut, inches	3/16	3/16	3/16
Tool angles—			
Clearance	6	6	6
Back slope	7½	8	8
Side slope	12	14	14
Nose	3/16″ radius	3/16″ radius	3/16″ radius
Test logs used (Refer to Table VIII for properties)	I and II	III	II

The tools varied in length from 8 to 11 inches and the holder in which they were used was 15 inches long. This consisted of 2 carefully machined U shaped sections with the bottom of the groove square, 17/32 inch wide and 3/8 inch deep; one section was placed above and the other below the tool and both were held in alignment by two dowel pins at each end. The holder with the tool in place was clamped in the four-bolt tool post shown in Fig. 2.

Cutting was done on test logs of about 15 inches diameter and 8 feet long, of forged and heat treated 3 per cent nickel steel such as is in wide commercial use for heavy forgings. One to two inches was removed from

the diameter after heat treatment and testing was stopped when the log had been cut down to 8 inches. The chemical and physical characteristics of these forgings are shown in Table VIII.

It will be noted that the test logs used in the 3 series of tests are quite

Table VIII

Properties of Test Logs Used

Log No.	I		II		III
Chemical composition, per cent—					
C	.34		.37		.30/.40
Mn	.59		.62		.50/.80
P	.043		.046		.05 max.
S	.034		.027		.05 max.
Si	.22		.12		.....
Ni	2.88		2.93		2.50/3.50
Cr	.02		.03		.....
Cu	.29		.32		.....
Tensile properties obtained on "transverse specimens"	End 1	End 2	End 1	End 2	
Prop. limit, lb./sq. in.	63,100	66,200	63,100	65,100	70,000
Tensile Str. lb./sq. in.	98,900	98,300	97,200	100,300	110,000
Elong. per cent in 2 in.	17.3	17.5	13.5	15.0	18.0
Red area, per cent	24.0	23.2	17.9	22.6	31.0
Brinell hardness	196	196	202	207	215

Table IX

Comparison of Performance of Various Brands of High Speed Steels Based on Data Given in Table XI

(Ten steels selected at random from those tested)

Brand	Average time of cut in minutes: 1st set of tests speed: 67 ft. per min.	2nd set of tests speed: 61 ft per min.	Position in list: 1st set of tests	2nd set of tests	Type steel
B	10.06	10.32	1	3	Low W
C	8.80	11.68	2	2	Low W
O	7.87	7.36	3	6	High W
S	7.60	14.56	4	1	Cobalt
T	6.18	8.92	5	5	Special (Mo)
Q	5.52	9.41	6	4	Cobalt
H	4.90	6.15	7	9	High W
R	4.85	7.25	8	7	Cobalt
W	4.14	6.39	9	8	Special (U)
F	4.01	4.87	10	10	High W

similar and uniform throughout, as far as may be judged by the tensile properties and hardness. Without doubt, however, variations in machinability exist, so that one tool of each brand was tested before the second tools were used. The latter were then tested in order before the third tool of each brand was tried. Such regulation of the sequence of testing almost certainly renders physical variations in the test logs negligible in their effect upon results obtained. At least this procedure goes as far toward obtaining uniformity in large masses of metal as can reasonably be expected. The feed used in all tests was 0.045 inch per revolution and the depth of cut 3/16 inch; the desired cutting speed, determined on the bottom of cut, was 67 feet per minute in test No. 1, 61 feet per minute in No. 2 and 60 feet per minute in test No. 3 (See Table VII).

Before starting any test, great care was taken to remove the glazed

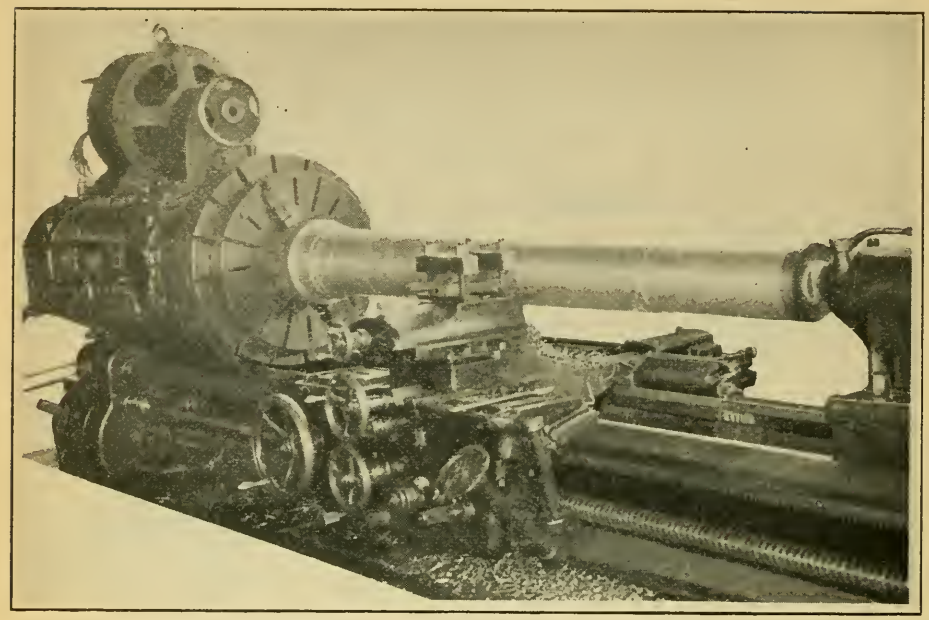


Fig. 2—Type of lathe and tool holder used in the cutting tests described.

surface of the log remaining after the breakdown of the previous tool and also any particles of the tool which may have been ground into the surface of the metal being cut. The tool to be tested was then forced against one side of the U shaped grooves in the holder and set to project beyond the end of it by 3/4 inch. The holder was next clamped in the tool post so that the side of the tool was at right angles to the log surface, the top level and the end of the nose on dead center. After adjusting the speed of the lathe

Table X

Comparison of Performance of Various Types of High Speed Tool Steels in Three Series of Lathe Tests.*

Group or steel	Performance, as per cent of best type				
	1st series	2nd series	3rd series	Total	Average
Low tungsten steels	100	94.1	100	294.1	98
Cobalt steels	67.8	100	97.3	265.1	88
High tungsten steels	56.3	55.3	64.2 (uranium)	175.8	59
Special steels (Mo or U added)	54.6	69.0	51.7	175.3	58
Medium tungsten steels	54.1	55.8	62.4	172.3	57
Special cobalt-molybdenum steel	...	...	84	....	..
Tungsten-less steel	44.4	...	17.7	62.1	31

* Details of tests given in Tables VII, VIII, XI and XII.

to give the desired surface speed to the log, the tool was fed in by hand (having previously been adjusted to proper depth) until it took a full cut; the automatic feed was then thrown in and the time observed. Breakdown was sharp in all cases and left no doubt as to the time of any run. The tools of the first set were tested on logs I and II, those of the second on log III and those of the third on log II.

Table XI

Compositions, Heat Treatments and Lathe Tool Performance of Modern High Speed Tool Steels—(1st and 2nd Series of Tests)

Type of Steel	Brand	Chemical Composition, per cent C	Mn	P	S	Si	Cr	W	V	Co	Mo	U	Manufacturer's recommended heat treatment: Pre-heat temp., deg. F.	High heat temp., deg. F.	High heat time min.	Tempering medium	Tempering temp., deg. F.
Low tungsten - high vanadium	A	.64	.43	.019	.025	.15	3.43	12.72	1.85	...	...	..	1500	2300	1-1-½	Salt	1000
	B	.60	.31	.023	.026	.35	4.29	13.32	2.15	...	...	..	1500	2400	1-1-½	Oil	500
	C	.64	.26	.026	.016	.37	3.38	13.07	1.98	...	...	..	1500	2350	1-1-½	Salt	1050
Medium tungsten	D	.66	.23	.035	.018	.43	4.54	14.08	2.07	...	...	..	1500	2300	1-1-½	Salt	1050
	E	.71	.23	.032	.027	.24	4.67	14.31	1.75	...	...	..	1500	2350	1-1-½	Salt	900
High tungsten-low vanadium	F	.65	.29	.031	.021	.17	3.77	17.73	.98	...	...	..	1500	2300	1-1-½	Muffle furnace	1050
	G	.84	.32	.018	.024	.42	3.83	16.13	1.24	...	...	..	1500	2300	1-1-½	Salt	1050
	H	.68	.10	.018	.025	.20	2.95	19.64	.93	...	...	..	1500	2500	1-1-½	Salt	1100
	I	.75	.29	.018	.022	.28	3.69	18.27	.98	...	...	..	1500	2300	1-1-½	Oil	700
	J	.64	.24	.015	.016	.43	3.00	16.98	.87	...	...	..	1500	2350	1-1-½	Salt	1050
	K	.57	.17	.022	.020	.35	4.37	17.58	.79	...	...	..	1500	2300	1-1-½	Salt	1100
	L	.85	.26	.016	.024	.20	2.26	17.05	.96	...	...	..	1500	2300	1-1-½	Muffle furnace	825
	M	.80	.20	.024	.029	.34	2.84	17.86	.73	...	...	..	1500	2300	1-1-½	Oil	450
	N	.66	.22	.024	.025	.25	3.24	17.03	.87	...	...	..	....	....	....	....	....
	O	.65	.12	.021	.029	.23	3.43	17.31	1.17	...	...	..	1500	2350	1	Salt	1100
Cobalt steels	P	.68	.19	.018	.021	.37	3.96	13.07	1.63	1.86	...	..	1500	2350	1-1-½	Salt	1050
	Q	.67	.42	.023	.023	.39	3.72	13.50	1.28	4.23	...	..	1500	2300	1-1-½	Salt	1000
	R	.66	.20	.022	.019	.45	3.45	17.80	1.06	2.54	...	..	1500	2300	1-1-½	Salt	1050
	S	.58	.09	.016	.026	.18	2.78	17.56	.93	3.35	...	..	1500	2500	1	Salt	1100
Special steels— (Molybde'm added)	T	.69	.23	.027	.017	.42	3.52	12.88	1.97	...	.71	..	1500	2350	1-1-½	Salt	1050
	U	.64	.23	.014	.020	.42	3.58	16.65	1.10	...	.71	..	1500	2350	1-1-½	Salt	1050
(Uranium added)	V	.66	.18	.035	.027	.39	3.94	13.80	1.45	...	...	.23	1500	2350	1-1-½	Salt	1100
	W	.64	.26	.027	.027	.17	3.21	17.03	.86	...	...	.26	1500	2350	1-1-½	Salt	1100
(Tungsten-less)	CC	.65	.55	.027	.044	.48	4.62	....	.68	4.73	4.72	..	1500	2010	15	Salt	900

Table XI (Continued)

Type of Steel	Brand	First set of tests: First grind B1	B2	B3	B4	B5	Av.	Endurance in minutes: Re-grind B1	B2	B3	B4	B5	Av.	Av. both grinds	Av. all tests by gr'ps
Low tungsten—high vanadium	A	....	13.75	6.62	14.98	7.65	10.75	10.83	5.45	5.10	9.65	6.23	7.45	8.92	...
	B	12.53	11.47	8.70	10.75	9.63	10.62	7.93	13.27	8.58	9.48	8.23	9.50	10.06	...
	C	10.05	9.45	9.90	10.13	11.77	10.26	7.18	7.03	9.00	8.48	5.00	7.34	8.80	9.27
Medium tungsten	D	9.52	6.13	4.58	6.12	4.20	6.11	3.38	4.80	5.37	3.27	3.10	3.98	5.05	...
	E	5.45	4.32	4.25	5.35	5.20	4.91	5.37	4.10	6.45	5.45	4.10	5.09	5.00	5.02
High tungsten-low vanadium	F	....	5.15	3.33	5.93	4.40	4.70	3.10	3.50	4.43	3.22	3.03	3.46	4.01	...
	G	....	6.93	9.78	9.85	10.27	9.21	10.27	10.02	9.78	8.70	8.55	9.46	9.35	...
	H	3.00	6.08	5.55	5.73	4.52	4.98	5.97	4.87	5.28	4.85	3.17	4.83	4.90	...
	I	5.80	5.82	4.83	6.45	6.08	5.80	4.43	4.37	6.10	4.58	3.68	4.63	5.21	...
	J	3.00	3.13	2.95	3.70	2.80	3.12	2.70	2.22	2.95	2.40	2.97	2.65	2.88	...
	K	3.80	2.00	3.02	3.20	5.60	3.52	2.07	1.70	3.18	2.17	3.17	2.46	2.99	...
	L	4.92	5.55	4.40	7.53	8.80	6.24	2.87	6.67	4.53	5.08	5.30	4.89	5.56	...
	M	4.40	4.73	3.87	4.90	3.65	4.31	5.95	3.62	5.33	3.70	4.70	4.66	4.48	...
	N	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	O	6.62	7.03	6.82	6.80	6.27	6.71	6.67	10.33	11.28	9.57	7.35	9.04	7.87	5.22
Cobalt steels	P	5.43	9.73	7.88	8.92	7.77	7.95	4.82	6.13	8.00	5.97	7.22	6.43	7.19	...
	Q	6.38	5.95	5.63	4.92	6.88	5.95	3.73	4.48	6.53	4.82	5.83	5.08	5.52	...
	R	....	9.12	3.88	7.77	3.95	6.18	4.17	4.83	3.42	4.07	2.47	3.79	4.85	...
	S	10.10	9.13	9.95	8.03	8.33	9.11	6.17	5.60	8.28	5.83	4.58	6.09	7.60	6.29
Special Steels— (Molyb'm added)	T	5.08	5.00	6.53	7.57	8.10	6.46	7.02	5.05	5.18	7.28	5.00	5.91	6.18	...
	U	2.73	3.93	5.12	4.35	5.60	4.35	2.22	2.52	4.35	2.67	3.18	2.99	3.67	4.92
(Uranium added)	V	6.60	8.78	7.32	5.57	7.25	7.10	5.45	5.58	6.05	5.72	4.52	5.48	6.28	...
	W	4.00	4.68	3.18	4.60	4.75	4.24	4.65	3.60	4.27	4.90	2.82	4.05	4.14	5.21
(Tungsten-less)	CC	4.51	4.52	....	....	....	....	4.15	3.27	....	....	....	....	4.11	...

Table XI (Continued)

Type of Steel	Brand	Second set of tests — First grind 1	2	3	4	5	Av.	Endurance in minutes — Re-grind 1	2	3	4	5	Av.	Av. all tests both gr'ds	Av. all tests by gr'ps
Low tungsten–high vanadium	A	....	8.50	7.14	5.30	7.43	7.09	9.48	9.29	5.64	9.04	8.53	8.40	7.82	....
	B	....	9.31	9.12	Tool broke	10.70	9.71	10.06	10.20	9.43	Tool broke	11.58	10.32	10.06	....
	C	....	7.23	9.70	8.50	20.76	11.78	9.01	9.75	9.97	8.21	21.95	11.55	11.68	9.85
Medium tungsten..	D	....	5.07	6.34	5.06	7.76	6.06	3.34	5.34	5.92	5.02	5.97	5.12	5.54	....
	E	....	4.70	9.02	4.59	5.70	6.00	6.74	4.55	7.18	4.97	7.92	6.27	6.15	5.84
High tungsten–low vanadium	F	....	5.39	3.70	5.63	5.04	4.94	4.12	5.93	4.29	5.67	4.07	4.82	4.87	....
	G	....	5.90	5.80	4.53	7.39	5.90	6.55	6.52	6.95	6.31	6.87	6.64	6.31	....
	H	....	4.10	8.36	3.97	9.85	6.57	4.82	6.33	3.93	7.68	6.34	5.82	6.15	....
	I	....	5.46	8.53	5.30	7.97	6.82	5.60	8.54	6.71	7.00	14.70	8.51	7.76	....
	J	....	2.63	4.57	3.73	4.13	3.76	4.31	2.91	5.56	2.77	5.44	4.20	4.01	....
	K	....	2.84	7.80	3.84	3.34	4.46	4.48	2.88	5.01	3.27	4.46	4.02	4.22	....
	L	....	6.68	7.74	5.82	4.95	6.30	7.80	5.90	5.10	6.62	6.43	6.37	6.34	....
	M	....	3.97	5.82	4.41	5.15	4.84	6.07	4.29	5.87	4.05	5.75	5.21	5.04	....
	N	....	3.95	8.61	4.07	5.52	5.54	5.72	3.85	7.97	4.21	8.10	5.97	5.78	....
	O	....	5.43	7.91	4.95	7.65	6.48	9.34	6.63	10.10	5.29	8.96	8.06	7.36	5.78
Cobalt steels	P	....	7.76	12.39	9.60	8.58	9.58	11.35	6.19	14.03	11.23	14.20	11.40	10.60	....
	Q	....	7.27	9.30	6.78	11.93	8.82	7.99	9.87	7.45	9.21	14.87	9.88	9.41	....
	R	....	6.53	6.37	6.97	9.59	7.36	5.95	8.17	6.17	7.27	8.25	7.16	7.25	....
	S	....	11.83	15.21	8.88	22.02	14.48	15.16	12.81	12.57	8.56	24.18	14.66	14.56	10.46
Special steels— (Molyb'm added)	T	....	5.48	8.98	7.33	9.62	7.85	10.23	6.67	13.37	6.84	11.75	9.77	8.92	....
	U	....	4.81	7.89	5.84	7.55	6.52	6.59	3.19	6.93	5.75	8.24	6.14	6.31	7.62
(Uranium added)	V	....	5.87	6.96	6.09	7.34	6.56	6.96	7.82	6.60	9.30	8.17	7.77	7.23	....
	W	....	4.59	6.77	4.96	6.84	5.79	5.25	4.26	9.67	5.03	10.15	6.87	6.39	6.81
(Tungsten-less).	CC	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Discussion of Results

Brand Comparisons

A number of interesting and instructive features are revealed in the results of these tests. The average time that tools of any one brand will cut is greater in some instances after the first grind than after the re-grind. For certain brands the reverse is found to be true while the two averages obtained are often practically the same but none of these three conditions can be considered characteristic of any one type of steel. Large differences in performance of individual tools are observed when made from one bar of steel or when testing both ends of a short tool which has been hardened over its entire length (Table XII).

It is therefore necessary to test a relatively large number of tools and also to repeat the test after they have been re-ground at least once, if results or comparisons of value are to be obtained.

Various brands in the same group show differences in performance which cannot be ascribed solely to variations in chemical composition or heat treatment (for example, steels J and O) but in most cases comparable results were obtained. However, the order of value of different brands of nearly similar performance may be entirely changed by a modification in test, as shown in Table IX, or by substitution of tools from several lots of the same steels for those originally tested. It is therefore necessary to use care in making comparisons. Severe breakdown tests, such as those described will show markedly inferior tools, whether this inferiority is due to the quality of the steel, improper heat treatment, a combination of these or other causes, but the grading of brands of nearly similar performance, often made use of in the purchase of high speed tool steels, is not justified and if made is of no value. This distinction in interpretation of results has usually been overlooked, or at least not sufficiently emphasized by those who have carried out and made use of comparative tests of a similar nature.

Fig. 3—Typical failures of roughing lathe tools in severe breakdown tests, about ½ size. Note the rubbing off of the nose and "gutter" or groove worn on the top surface of the tools. Fig. 4—"Freezing" of the last thin chip to the nose of tool.

Group Comparisons

In group comparisons, similar precautions are to be observed but some significant variations in the performance of different types are evident as shown in Table X, in which the highest average endurance in each of the 3 series of lathe tests is rated as 100 per cent and the remaining groups given their respective valuations. There is no doubt that the low tungsten-high vanadium and cobalt steels, as groups, are the best. An attempt to differentiate between these, based on the results obtained, would be of little value as their relative positions vary in the several tests without very marked differences in performance. Medium and high tungsten steels and those containing molybdenum or uranium show comparable endurance which may be

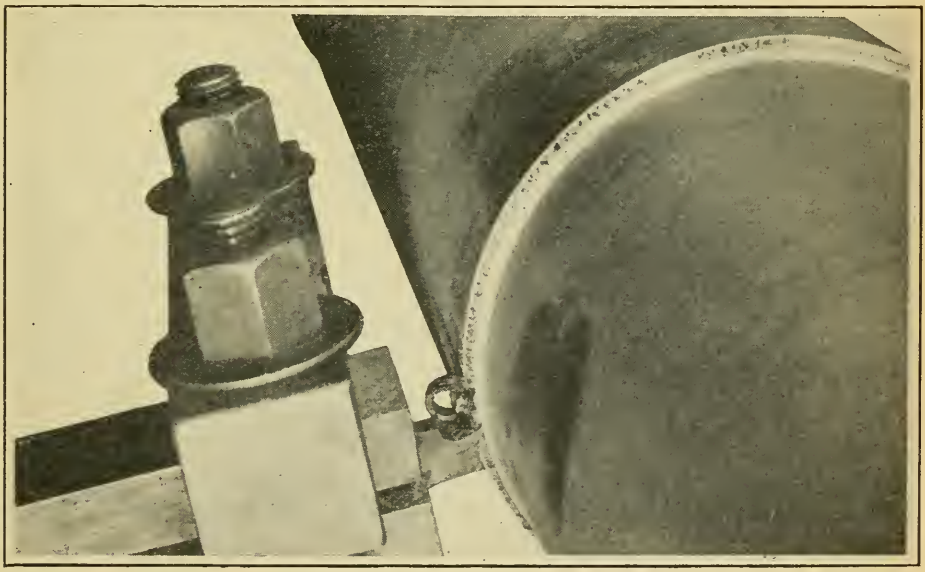


Fig. 5—Failure of a tool under test. Shows "glaze" produced on the test log.

Table XII
Compositions, Heat Treatments and Lathe Tool Performance of Modern High Speed Tool Steels—(3rd Series of Tests)

Type of steel	Brand	Chemical Composition, Per Cent C	Mn	P	S	Si	Cr	W	V	Co	Mo	U	Size of original bar, inches	Pre-heat temp., deg. Fahr.	High heat temp., degrees Fahr.	High heat time, min.	Quenching oil	Tempering temp., deg. F.
Low tungsten—high vanad'm	A	.64	.43	.019	.025	.15	3.43	12.72	1.85	...	...	...	1x1½	1600	2300	8	No. 2	Heated with muffle furnace from room temperature to 1090-1100°F., held 30 minutes and cooled in air.
		.74	.31	.008	.055	.51	3.56	13.05	1.73	...	...	...	1x⅝	1600	2300	8	No. 2	
	B	.60	.31	.023	.026	.35	4.29	13.32	2.15	...	...	...	1x½	1600	2300	7	No. 2	
		.73	.49	.012	.028	.37	3.30	13.36	1.71	...	...	...	1x⅝	1600	2300	3	Sperm	
		..	..	...	...	..	...	....	...	...	...	...	1x⅝	1600	2365	3	Sperm	
Medium tungsten	E	.71	.23	.032	.027	.24	4.67	14.31	1.75	...	...	...	1x½	1500	2415	3	No. 2	
		.62	.14	.046	.040	.20	3.50	15.50	1.63	...	...	...	1x⅝	1500	2415	3	No. 2	
		..	..	...	...	..	...	....	...	...	...	...	1x⅝	1500	2370	12	No. 2	
	D	.66	.23	.035	.018	.43	4.54	14.08	2.07	...	...	...	1x½	1600	2415	7	No. 2	
High tugsten—low vanadium	F	.69	.32	.001	.033	.18	3.80	18.00	.87	...	...	...	1x⅝	1600	2415	8	No. 2	
	X	.67	.19	.008	.057	.37	3.33	17.72	1.06	...	...	...	1x⅝	1600	2415	2	No. 2	
	Y	.63	.20	.009	.027	.21	3.05	18.71	.87	...	...	...	1x⅝	1600	2415	7	No. 2	
Cobalt steels..	Q	.76	.34	.008	.061	.27	3.41	14.21	1.52	4.73	...	...	1x2	1600	2300	3	Sperm	
	R	.66	.20	.022	.019	.45	3.43	17.80	1.06	2.54	...	...	1x¼	1600	2415	6	No. 2	
	S	.58	.09	.016	.026	.18	2.78	17.56	.93	3.35	...	...	1x½	1600	2415	7	No. 2	
		..	..	...	...	..	...	....	...	...	...	...	1¾x½	1600	2415	3	Sperm	
		..	..	...	...	..	...	....	...	...	...	...	.....	....	2385	7	No. 2	
		.72	.08	.020	.017	.11	3.26	18.40	.86	3.10	...	...	1x½	1600	2415	3	Sperm	
		.55	.42	.004	.063	.14	3.10	17.48	.75	3.78	...	...	.....	1600	2415	3	Sperm	
Special steels—(Uran'm added)	V	.66	.18	.035	.027	.39	3.94	13.80	1.45	...	...	.23	1x½	1600	2300	7	No. 2	
	W	.64	.26	.027	.027	.17	3.21	17.03	.86	...	...	.26	1x½	1600	2415	7	No. 2	
(Cobalt - molyb'm added)	Z	.65	.28	.028	.045	.28	4.25	17.70	1.00	4.88	1.07	...	1x⅝	1600	2415	3–8	No. 2 or Sperm	
(Tungst.-less)	CC	.65	.55	.027	.044	.48	4.62	....	.68	4.73	4.72	Ni 1.03 Cu .12	Forged from 2x3	1500	2010	15	Sperm	900 45 min.

Table XII continued

Type of steel	Brand	First grind, endurance in minutes 1	1A	2	2A	3	3A	Av. per brand	Re-grind, endurance in minutes 1	1A	2	2A	3	3A	Av. per brand	Av. per brand both grinds, min.	Av. all tests by groups, min.
Low tungsten-high vanadium	A	10.42	11.54	....	....	....	....	....	16.58	4.82	....	....	....	....	....	....	....
		16.37	3.52	....	....	....	....	10.46	17.72	5.72	....	....	....	....	11.21	10.84	....
	B	9.70	19.02	....	....	....	....	....	15.19	7.72	....	....	....	....	....	....	....
		11.12	5.42	16.99	32.38	....	....	....	5.13	9.67	12.42	42.13	....	....	....	....	....
Med. tungsten ...	E	13.13	15.05	....	....	....	....	15.36	5.51	7.17	....	....	....	....	13.12	14.24	13.11
		15.48	8.82	....	....	....	....	....	5.51	9.60	....	....	....	....	....	....	....
		6.85	9.65	....	....	....	....	....	8.19	5.95	....	....	....	....	....	....	....
		9.38	18.52	....	....	....	....	9.81	9.85	8.15	....	....	....	....	7.88	8.85	....
	D	8.68	4.23	....	....	....	....	....	10.53	4.92	....	....	....	....	....	7.09	8.41
Hi. tungsten-low vanadium	F	5.53	4.82	5.99	7.27	....	....	....	8.28	7.05	7.68	7.50	....	....	....	6.76	....
	X	11.70	7.98	....	....	....	....	....	9.52	9.64	....	....	....	....	....	9.71	....
	Y	9.92	11.17	8.17	6.03	....	....	....	12.07	10.52	7.33	5.17	....	....	....	8.80	8.17
Cobalt steels ..	Q	10.65	23.58	10.84	22.85	28.08	13.27	....	16.97	broke	9.22	11.53	17.95	10.92	....	....	....
	R	broke	6.52	....	....	....	....	16.54	broke	8.07	....	....	....	....	12.61	14.73	....
	S	13.37	21.47	....	....	....	....	....	6.08	25.05	....	....	....	....	....	16.50	....
		5.80	10.03	....	....	....	....	....	....	....	....	....	....	....	....	....	....
		8.47	26.25	14.27	7.65	....	....	....	5.65	6.57	....	....	....	....	....	....	....
		....	....	....	....	....	....	....	5.42	10.23	10.67	7.25	....	....	....	....	....
		9.57	10.38	....	....	....	....	....	10.80	10.67	....	....	....	....	....	....	....
		11.25	11.15	....	....	....	....	11.48	18.52	12.80	....	....	....	....	9.86	10.67	12.73
Sp. steels—(Uran. added) .	V	10.97	5.28	....	....	....	....	....	5.23	4.23	....	....	....	....	....	6.43	....
	W	6.52	6.70	....	....	....	....	....	10.62	4.64	....	....	....	....	....	7.12	6.78
(Cobalt-molyb. added).	Z	12.58	7.72	1.35	13.75	13.60	6.77	....	13.92	18.40	7.67	22.00	9.07	4.42	....	10.93	10.93
(Tungsten-less)..CC		2.94	2.07	....	....	....	....	....	2.04	2.26	....	....	....	....	....	2.32	2.32

rated as roughly 60 per cent of that of the low tungsten-high vanadium steels. A tungsten-less high speed tool steel introduced for comparative purposes has a rating of approximately 30 per cent.

The relatively poor showing of the high tungsten steels is significant, especially since they represent the most popular type now manufactured in this country. Many of those tested are well known brands produced by manufacturers who are known to take all reasonable precautions to insure the

Table XIII

Average Energy Consumed by Various Modern High Speed Tool Steels in Severe Lathe Cutting Tests

(Data obtained during 1st set of tests covering tools listed in Table XI)

		Av. Net Watts Consumed by Tools												Av.
		First Grind						Second Grind						both Group
Type of steel	Brand	B1	B2	B3	B4	B5	Av.	B1	B2	B3	B4	B5	Av. grinds	Av.
Low tungsten-high vanadium steels	A	....	4130	4760	4321	4582	4453	4086	4172	4872	4391	4557	4416	4432	....
	B	3987	4298	4647	4348	4438	4344	4592	4265	4793	5022	4567	4648	4496	....
	C	4005	3868	4784	4523	4462	4328	4199	4514	4366	3898	4752	4346	4337	4422
Medium tungsten steels	D	3912	4442	4677	4720	4482	4447	4495	4798	4572	4240	4839	4589	4518	....
	E	4266	4434	5059	4722	3997	4496	3885	4810	4726	4715	4309	4489	4492	4505
High tungsten steels	F	....	4116	4956	4245	4629	4486	4146	4348	5077	4345	4566	4616	4492	....
	G	....	4140	4654	4321	4793	4477	4458	4328	4845	4329	4665	4525	4504	....
	H	3869	3998	4583	4432	4292	4235	4462	4593	4908	4101	4689	4551	4393	....
	I	4220	3936	4618	4350	4625	4350	4483	4982	4569	4081	4728	4569	4459	....
	J	4147	4319	4545	4518	4021	4310	4744	4589	4218	4442	4355	4470	4390	....
	K	4126	4668	4495	4973	4192	4491	4863	4772	4587	4567	4506	4659	4575	....
	L	4189	4480	5251	4813	4410	4429	4187	4660	4618	4659	4322	4489	4459	....
	M	4038	5130	4764	4550	4205	4537	4108	4755	4563	4693	4602	4544	4541	....
	N	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	O	4243	3994	4482	4289	3778	4157	4411	4546	4456	4262	4223	4380	4268	4354
Cobalt steels	P	4257	4494	5032	4781	4767	4466	4131	4583	4696	4521	4066	4399	4433	....
	Q	4225	3957	4766	4603	4555	4421	4393	4760	4508	4352	4790	4561	4491	....
	R	....	3932	4556	4373	4549	4352	3828	4037	4710	4345	4592	4302	4325	....
	S	4010	3985	4642	4545	4511	4339	4490	4770	4332	4243	4814	4530	4434	4313
Special steels—															
(Molybdenum added)	T	4000	4296	4440	4575	4041	4270	4459	4650	4705	4234	4003	4412	4340	....
	U	4079	4382	4695	4710	4307	4435	4294	4872	4098	4350	4488	4420	4428	4384
(Uranium added)	V	4132	3884	4550	4459	4299	4265	4696	4709	4645	4361	4713	4625	4445	....
	W	3966	4036	4617	4830	4320	4354	4663	4476	4368	3890	3964	4272	4313	4379

quality of their product, so that the observed inferiority would not naturally be ascribed to generally poor quality of steel, but rather to the fact that the average endurance of this group is less than that of the low tungsten-high vanadium steels or that the heat treatments employed were not the best that could be used. Probably both are contributary causes. The fact that steels containing 1/4 per cent uranium did not develop exceptional performance is in agreement with results obtained by Langhammer[5] under entirely different and more moderate working conditions and likewise with the opinion held by Mathews[6] who recently stated—"so far as our experience goes we have been unable to see that it (uranium) confers any specific benefit."

An interesting feature developed in the first two sets of tests is that a change in working conditions including small variations in tool angles but mainly a decrease in cutting speed from 67 to 61 feet per minute produced a much larger increase in the average endurance of steels containing cobalt or special elements than in the plain chromium-tungsten-vanadium steels (basic

5. A. J. Langhammer: A Comparative Test Upon High Speed Steels. *Chem. & Met. Eng.* 22, pp. 829, 889, 939, 969.

6. J. A. Mathews: Modern High Speed Steel. *Proc.* A. S. T. M., 19, pt. 2, p. 141.

types). In this respect the cobalt steels show greater variation than those containing molybdenum or uranium and in one case, that of brand S, as much as about 90 per cent increase.

Character of Chips Produced and Failure of the Tools

Some quite definite and more or less regular variations in the character of chips produced during progress of the lathe tests were observed. Almost without exception a long "ribbon" of steel was obtained at the start. The first break would, of course, be largely dependent upon the character of support accorded the metal in its unguided travel but if held by tongs and pulled away from the test lathe an unbroken metal strip, often several hundred feet long, resulted. Shorter and shorter chips were produced as the tool continued to cut and these varied in length from about half a foot at the beginning of what may be called the second stage to a fraction of an inch just before failure. These characteristics were so generally representative that they became a rough indication of the quality of the tool soon after the beginning of the cut. Progressive decrease in length of chips is undoubtedly, largely caused by a gradual change in the most effective portion of the top surface of the tool resulting from abrasive action of the metal being cut. A groove or "gutter" is worn near the nose and forces the chip to curl more and more sharply as the wear increases and because of the cyclic variation in pressure[7] and the fact that the chip is already highly stressed the ribbon breaks into small sections instead of passing freely over the tool at approximately its original top angles. The wear on the entering side near the nose is also an important contributing factor particularly near the end of the cut and both effects are shown in Figure 3.

Breakdown is concomitant with the production of a "glaze" on the test log (Fig. 4). At the moment of failure which generally occurs suddenly, the dimensions of the chip decrease both in direction of the feed and depth of cut. This is probably caused by "springing" of the tool in the holder and is due to greatly increased pressure in all directions resulting from the "dulling" or rubbing away of the nose. If the tool is withdrawn from the test log at the first signs of failure the last thin chip produced will often "freeze" to the nose, as shown in Fig. 5, thus giving concrete qualitative evidence of the high pressure and temperature existing at the moment.

Power Consumption

Thus far, discussion of test results and comparisons have been on the basis of the time required to produce failure in tools working under definite cutting speeds, feeds, depth of cut, etc. Certain groups were shown to have repeatedly better performance than others despite certain small but definite changes in test conditions but the question which almost immediately arises is whether or not more power is consumed by any one set of steels over others in cutting metal at a given rate for equal times. Electric power is measured in kilowatt-hours and that consumed in equal time intervals is proportional to the average kilowatts (energy) during the interval, which may be obtained by ammeters and voltmeters or wattmeters.

The values given in Table XIII for tools used in test No. 1 show that the power consumed by various brands and groups is practically the same in all cases. Differences observed between individual tools are often greater than variations between different brands but are not large and cannot be considered to have any special significance. Thus, the various types of

7. See note (1) with particular reference to data given in folder 12.

high speed tool steels remove the same amounts of metal at equal rates with practically the same power consumption but some have greater endurance than others.

Moderate Breakdown Tests of 1 x ½-inch Roughing Type of Lathe Tool

It was pointed out at the beginning of this report that high tungsten-low vanadium high speed tool steels are the most popular type produced at the present time and subsequently it was shown that the endurance of this group in certain severe breakdown tests was generally much less than that of the cobalt or low tungsten-high vanadium steels. While the conditions under which

Table XIV

Effect of Variation in Feed on the Performance of Various Groups of High Speed Tool Steels

			Endurance in Minutes*			
Group	Brand	Tool No.	3rd grind (.031 feed)	4th grind (.031 feed)	Av. 3rd and 4th grinds (.031 feed)	Av. 1st and 2nd grinds (.045 feed)
Cobalt steels.....	S	x2A	23.60	22.83	....	....
	S	T1A	23.27	25.13	....	....
	Q	A104-14A	39.08	17.30	....	....
	Q	A104-14	25.42	15.42	24.00	14.36
High tungsten — low vanadium steels...	Y	A105-2A	17.27	22.30	....	....
	Y	A105-2	35.97	12.35	....	....
	F	A100-27	16.20	9.57	....	....
	X	A102-1	22.70	25.25	20.20	7.84
Low tungsten — high vanadium steels...	B	A101-26A	11.48	19.03	....	....
	B	A101-27A	13.52	12.82	....	....
	B	A101-26	22.48	10.45	....	....
	A	A103-41A	15.58	17.57	15.37	10.08

* Tools were ground to 6 degrees clearance, 8 degrees back slope and 14 degrees side slope with radius of nose 3/16-inch. Tests were made on log No. II at 60 feet per minute cutting speed, 3/16″ depth of cut and feeds shown.

these tests were made may represent those obtaining in actual practice it is true that a large part of the work for which high speed tool steels are used in various shops is carried out under more moderate working conditions which do not produce the high frictional temperatures obtained in the authors' tests. It is therefore patent to compare the various groups when subjected to more moderate service.

Four tools to represent each of the three most important groups were chosen from the various brands used in test No. 3, as shown in Table XIV. In this selection of tools already tested, an effort was made to obtain groups of 4 or 5 having nearly the same average performances as those obtained in the third set of tests. All tools were ground to form in exactly the same manner as in the previous experiments and the tests carried out represent the third and fourth grinds. They were made with the same test log, tool angles, cutting speed and depth of cut but with approximately three quarters of the feed used in test No. 3.

The relatively poor endurance of the high tungsten-low vanadium steels in the severe tests is not observed under the more moderate conditions of service in test No. 4, a feature which assists in explaining the popularity of the high tugnsten type for general roughing work. However, insufficient

tests have been made to determine whether the performance of the high tungsten steels is equal or better than that of the low tungsten high-vanadium type under the working conditions used.

Lathe Tests of Small Tools

Breakdown tests of large tools, such as have been described in previous sections of this report, are very expensive to make because they require large masses of uniform metal to be cut, heavy equipment and considerable time. The limitations in interpretation of data obtained, as already described, make it questionable whether information derived from repeating this type of test with various steels is commensurate with the cost (except in special instances) especially since comparable performance is observed in the majority of steels in any one group. At least the variation in performance of the various steels (with some exceptions) is not more than would be expected from different lots of the same brand supplied throughout a period of several months. If as much information or satisfactory comparisons could be obtained with smaller tools the cost of tests would be materially reduced.

Accordingly one large tool from each of the low tungsten, high tungsten and cobalt groups was annealed, cut into smaller tools, heat treated, ground and tested in a manner similar to that already described for the large tools. The dimensions of tool chosen were half those used in the first 4 sets of tests namely ½ x 1/4 inch and the radius of the nose was made 3/32 inch instead of 3/16 inch. Tool angles, speed, feed and depth of cut were exactly the same as those used in test No. 4, as was also the test log. On account of the sharper nose required in the small tools and their size, these test conditions, which were considered to be only moderately severe in the case of the large tools, may be considered as somewhat more so for the small tools but probably not equivalent to the severe working conditions obtaining in the first three sets of tests. Results obtained are given in Table XV.

As in the severe tests of large tools the low tungsten-high vanadium steel has better endurance than the high tungsten type but there is not such a large difference as was observed in the large tool tests. The magnitude of the observed effects cannot be compared as the change in size of tools is not the only variable introduced. The important feature is that the small tool tests, carried out under severe working conditions, once more show superiority of the low tungsten-high vanadium steel. The heat treatment of the high tungsten-cobalt steel was inadvertently changed and a low hardening temperature used which without doubt accounts for the relatively poor performance of the steel. It will also be noted that the variations in the performance of individual tools is in general no greater when testing the small tool bits than when using the large tools. However, the same precautions in making tests and in interpretation of results must be observed in both cases. The results obtained, therefore, indicate that when small tool tests are carefully carried out the sensitivity is such as to yield results of some value.

A most interesting feature is revealed in comparison of the performance of ½ x 1/4-inch and 1 x ½-inch tools when removing metal from the same test log under the same cutting speed, feed, depth of cut, etc. With the exception of the ½ x 1/4-inch tools prepared from the cobalt steel, which were hardened at a low temperature, the small tools removed more metal than the large ones before failure. There are a number of variables in the two sets of tests which, as previously mentioned, make inadvisable detailed comparisons of the values reported but it is doubtful whether any of the readily

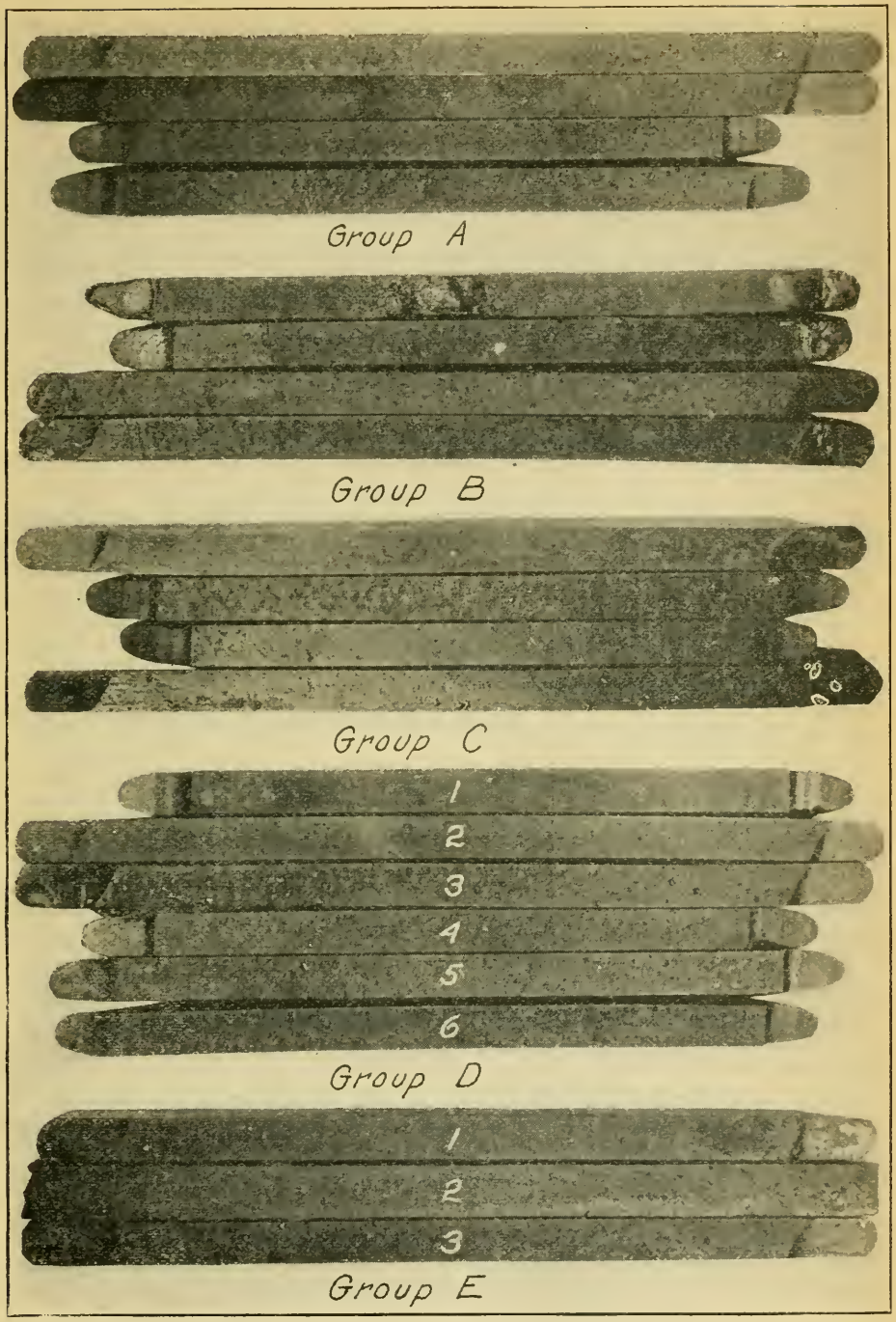


Fig. 6—Surface condition of tools made from various types of high speed tool steels oil quenched from the temperatures indicated: Group A—Low tungsten-high vanadium steels, heated to 2300 degrees Fahr. Group B—Medium tungsten steels, heated to 2370 or 2415 degrees Fahr. Group C—High tungsten-low vanadium steels, heated to 2415 degrees Fahr. D1, 2 and 6—High tungsten steels containing cobalt, heated to 2415 degrees Fahr. D3, 4 and 5—Low tungsten steels containing cobalt, heated to 2300 degrees Fahr. E1 and 4—Special high tungsten steel containing cobalt and molybdenum, heated to 2415 degrees Fahr. E2—High tungsten steel containing uranium, heated to 2415 degrees Fahr. E3—Low tungsten steel containing uranium, heated to 2300 degrees Fahr.

recognizable differences in these two sets of tests adequately account for this result and the authors do not at the present time offer any explanation.

Miscellaneous Tests

Secondary Hardness and Heat Treatment

Examination of Table XI in which are given the heat treatments recommended by different manufacturers shows that these vary widely for brands of the same type composition. High heat furnace temperatures from 2300 to 2500 degrees Fahr., and tempering temperatures between 450 and 1100 de-

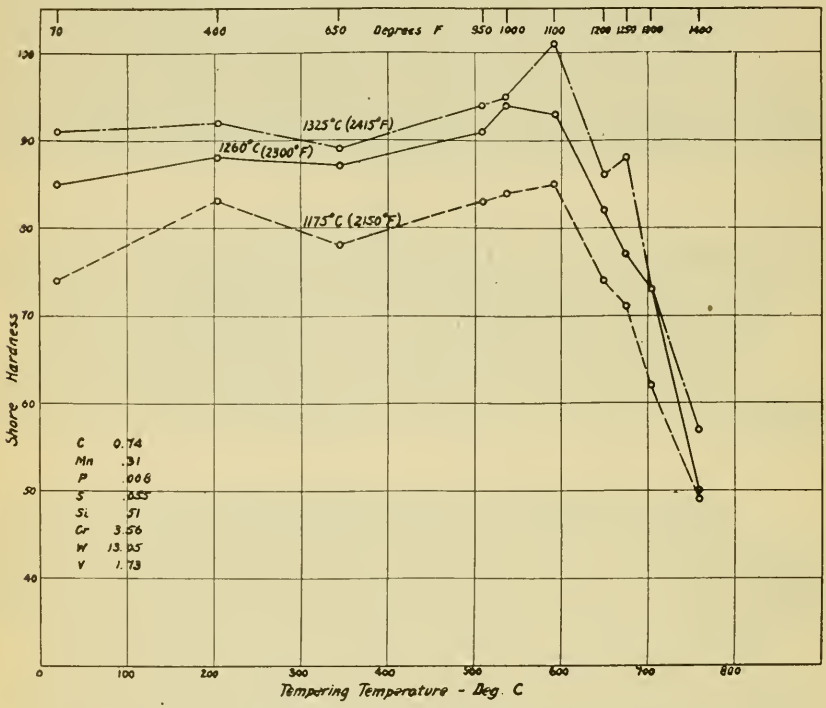


Fig. 7—Re-hardening upon tempering of low tungsten-high vanadium high speed tool steel first oil quenched from various temperatures.

grees Fahr. are found and indicate that there is not yet complete agreement as to the most suitable treatments to use under given working conditions.

The lathe tests made were primarily comparisons of brands or groups of steel and it is therefore not possible to consider in detail the effects of variations in heat treatment upon the performance of different type compositions. However, certain indications were obtained which made it desirable to carry out such special tests as determinations of secondary hardness, characture of fracture, etc. and the results are summarized in the following paragraphs.

1. High tungsten steels withstand high hardening temperatures of approximately 2400 degrees Fahr. better than do the medium or low tungsten steels. An indication of this difference is given by groups *B* and *C*, Fig. 6 in which is shown the surface condition of many of the tools used in test No. 3.

2. Low tungsten-high vanadium steels are more sensitive to heat treatment, especially with respect to variations in hardening temperatures between 2150 and 2400 degrees Fahr. than the high tungsten-low vanadium type. This is shown by the more rapid coarsening of structure observed in examination of fractures and by variations in hardness under varying treatments (Figs. 7 to 11 inclusive). Not only are the latter changes smaller in the high tungsten steels for variations in hardening temperatures but they are also less for changes in tempering. However the addition of cobalt to low tungsten steels appears to produce a more stable product.

This does not mean that a given change in high heat temperature,

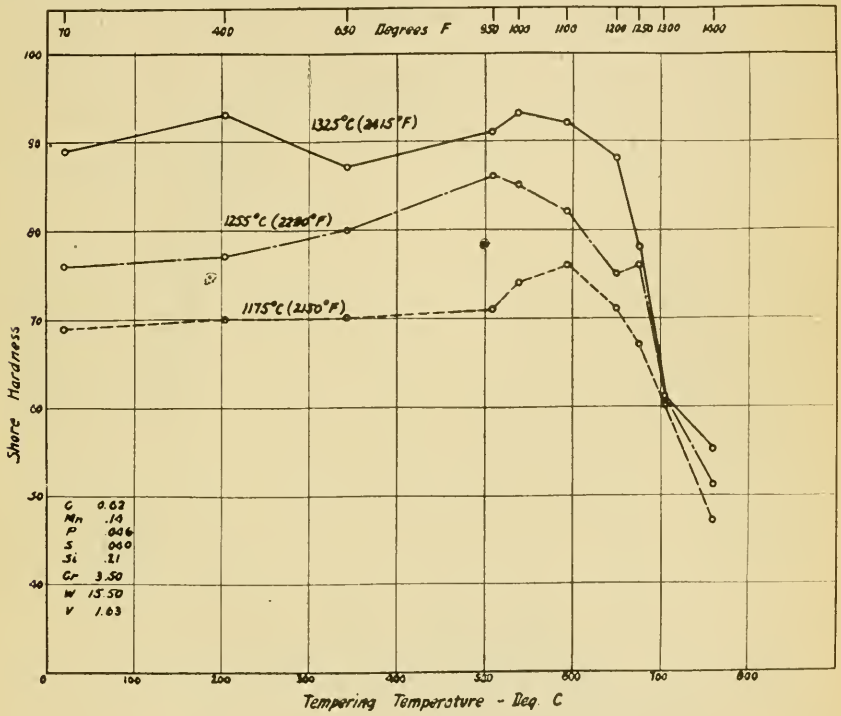


Fig. 8—Re-hardening upon tempering of medium tungsten high speed tool steel first oil quenched from various temperatures.

for example will affect the performance of low tungsten steels to a greater degree than that of the hight tungsten-low vanadium type. This might, however, be true under certain working conditions. The probable relation existing between heat treatment, hardness and cutting qualities of high speed tool steels has recently been summarized in a very clear and concise manner by Mathews[8] as follows:

"The lower the temperature at which the initial hardening is done, the lower will be the temperature at which the rehardening occurs on tempering, and presumably the sooner a tool so treated would fail in severe cutting where the frictional temperature was high. When the temperature in cutting is not extremely high we cannot conclude that the steel would fail sooner than one with a higher re-hardening temperature. In such cases, in my

8. J. A. Mathews: Modern High Speed Steel. *Proc.* A. S. T. M., 19, pt. 2, p. 141.

opinion, physical or mineralogical hardness plays an important part as distinguished from red hardness, but where the cutting conditions are severe it would appear logical that the higher the temperature of red hardening the longer the endurance of the tools."

Thus the various types of steel which showed marked differences in performance in severe service likewise show differences in their behavior under heat treatment and in physical properties which probably are of importance under more moderate working conditions.

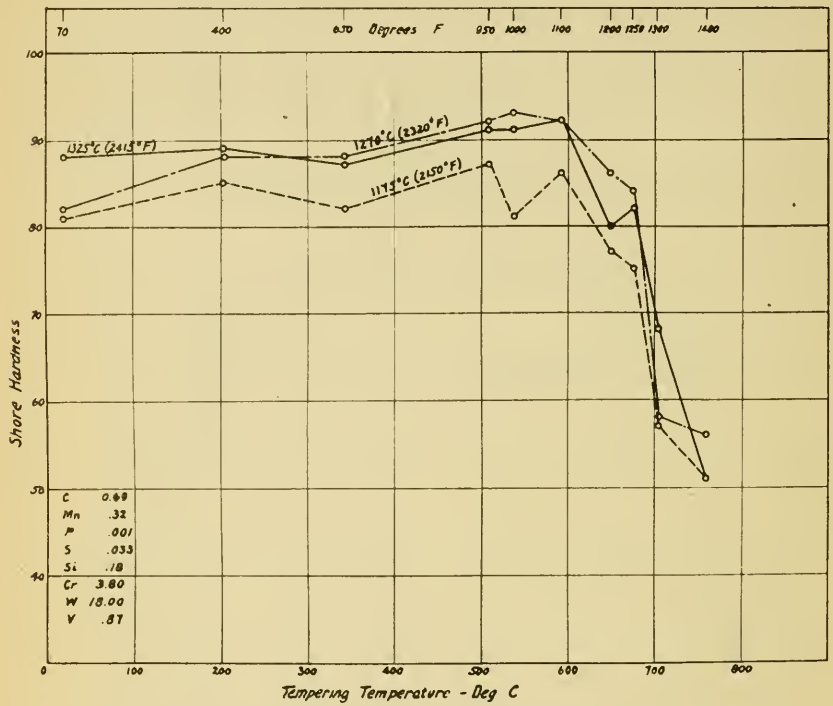


Fig. 9—Re-hardening upon tempering of high tungsten low vanadium high speed tool steel first oil quenched from various temperatures.

Microscopic Examination and Fractures

Mention has already been made of large differences in performance of tools made from the same bar of steel. While the reasons are often obscure on account of the large number of variables readily introduced into breakdown tests it is frequently possible to pick out the principal causes by use of the microscope and examination of fractures. A few illustrations taken from tools used in the cutting tests previously described are contained in Figs. 12 to 16 inclusive.

The appearance of fractures and structure may be very different for steels of similar chemical composition subjected to the same heat treatments whether comparisons are made between tools from the same bar of steel or from different lots or brands. For example, two of the high tungsten-low vanadium steels have moderately coarse fractures while that of steel X, of similar composition, is the finest of all examples contained in Fig. 12. The microstructure of this steel is shown in Fig. 14a and attention is called to the extremely fine grain size and uniformly distributed tungstides, car-

bides, etc. in contrast with the segregation shown in Figs. 14c and 15a. Such differences in structure originated during the progress of manufacture and cannot be eliminated by heat treatment. Steels like those shown in Figs. 14c and 15a often show "fish-scale fractures similar to that reproduced in Fig. 13 and in cutting tests, generally poor and erratic results are obtained.

General Discussion

Composition Versus Quality of Steel and Heat Treatment

Considerable emphasis has been placed on the chemical composition of high speed tool steels though mention has likewise been made of the neces-

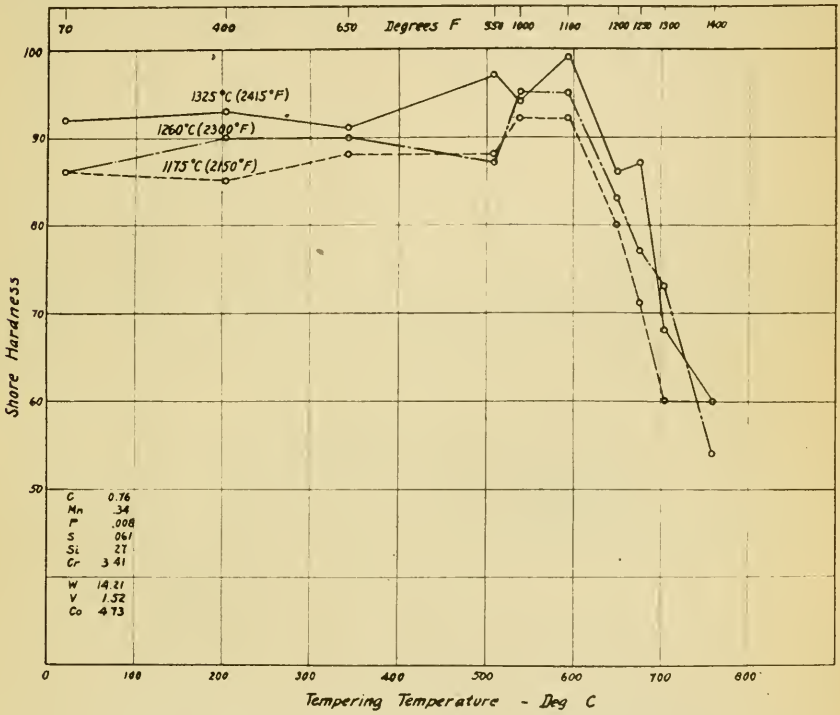


Fig. 10—Re-hardening upon tempering of medium-low tungsten high speed tool steel containing cobalt, first oil quenched from various temperatures.

sity of high grade raw materials, good melting practice and care in fabrication in producing alloys of superior performance. Clean, sound metal, free from impurities and excessive segregation including "stringers" of carbides, tungstides, etc. is essential and it is true that the behavior of 2 lots of practically identical composition and heat treatment may be quite different in service because of variations in the quality of the steel. However, its composition is likewise of importance and should not be disregarded. If it is not within certain limits the steel cannot have satisfactory performance; on the other hand, the mere fact that the metal comes within the ordinary limits of chemical composition does not insure its behavior in service.

The practice of purchasing and using high speed tool steels solely by name is not the ideal method for there is always the possibility of change of type resulting from a variety of causes. This may result in decreased performance with rise in tool costs or require a modification in treatment for

maintaining comparable service. While such conditions may not often be encountered they are nevertheless observed and therefore are of importance. In an instance recently brought to the attention of one of the author's two organizations were using the same brand of steel. In the first case low tungsten-high vanadium steel was regularly supplied while the second plant reported this brand to be the high tungsten-low vanadium type. In view of

Table

Heat Treatment and Performance of Small Lathe Tools

Brand	Pre-heat temperature, degrees Fahr.	High heat temperature, degrees Fahr.	High heat Time, Minutes	Tempering temperature, degrees Fahr.	First grind 1	2	3	4	5
B	Low tungsten—high vanadium steel								
	1600	2300	2	1090	26.90	31.75	25.95	24.28	28.78
F	High tungsten—low vanadium steel								
	1600	2415	2	1090	24.38	36.10	20.83	26.85	16.33
R	Cobalt steel (high tungsten type)								
	1600	2300	2	1090	25.73	23.93	30.37	15.83	14.47

*Tools broke in test.

Size of tools: ¼″ x ½″ with radius of nose $\frac{3}{32}$″. Tool angles and properties of test log same as those

the test data previously described no further comments regarding such a condition need be made.

A lot of a well known brand, normally of the high tungsten type containing about 1 per cent vanadium recently gave one organization considerable

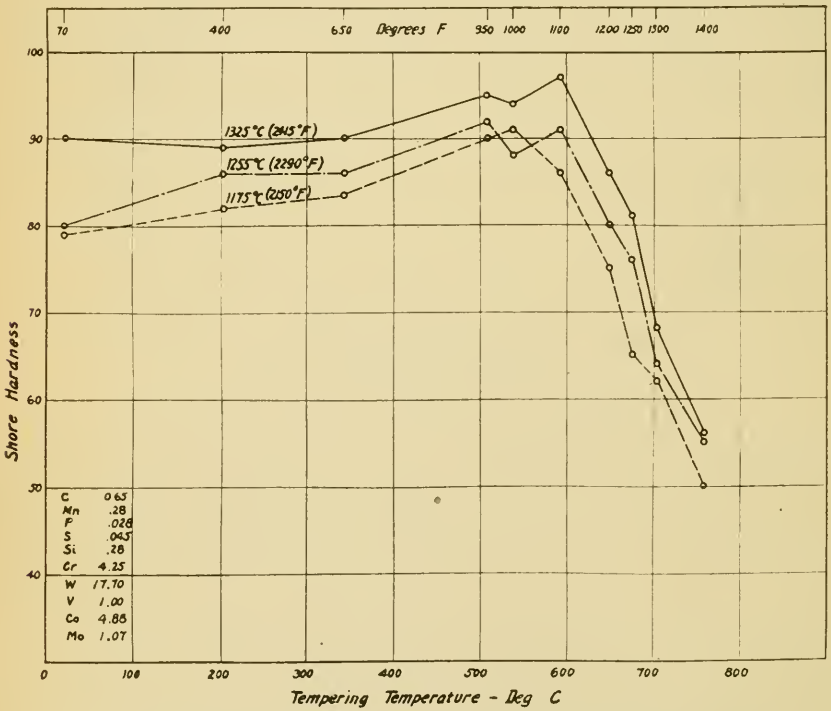


Fig. 11—Re-hardening upon tempering of high tungsten high speed tool steel containing cobalt and molybdenum, first oil quenched from various temperatures.

trouble and had only about 1/5 its ordinary endurance. Examination developed the fact that less than 0.2 per cent vanadium was present. This material was

undoubtedly shipped in error and no difficulty would be encountered in obtaining replacement but the cost in time and labor of such errors, to the many shops not ordinarily checking the composition of high speed tool steels but buying and using them solely by name, is of considerable magnitude.

Having secured steel of satisfactory quality and of suitable composition great care is required in heat treatment. Methods including accurate temper-

XV

Prepared from Three Types of High Speed Tool Steels

Endurance in Minutes	Re-grind						Average both grinds	Performance, per cent of best type
6	1	2	3	4	5	6		
22.15	32.40	29.97	17.40	.....	.....	.....	26.62	100
17.43	30.22	26.03	27.65	.....	.....	19.87	24.57	92
21.63	*	*	*	*	20.38	20.38	21.99	81

used in Test Series No. 3, Tables VII and VIII.

ature control but disregard of the time factor are not satisfactory. When it is considered that in many cases lathe tools are placed in heat treatment furnaces which are maintained at temperatures sufficient to melt the steel (See Figs. 14b, 15a, 15b and 16) and that therefore the time element, is largely depended upon in correctly carrying out the hardening operation it is not difficult to understand why erratic and unsatisfactory results are so often produced.

Breakdown Tests for the Purchase of High Speed Tool Steels

The chemical composition, quality of metal and heat treatment are three most important factors to be considered in the purchase of high speed tool steels. The advice of manufacturers can readily be obtained regarding available types best suited for definite service or if desired comparative cutting tests can be made. No difficulties should then be encountered in securing steel within satisfactory limits of composition.

While heat treatment is normally under complete control of the consumer it becomes of importance in selecting the type of steel. For example, slight superiority in performance of one composition might be counterbalanced by greater sensitivity to heat treatment or the necessity of using very high hardening heats for development of maximum endurance resulting in excessive scaling of tools, shorter furnace life and generally higher production costs. Assuming correctly balanced composition and heat treatment, the quality of metal may be considered as the summation of all other factors influencing the true performance of the steel. It is largely because of variations in this respect, that competitive breakdown tests have come into use though their purpose is comparison of finished products, the performance of which is influenced by all factors mentioned. It is questionable, however, whether such tests have really answered the purpose.

As already indicated the grading of brands or steels of nearly similar performance is not justified because the order of value may be entirely changed by minor variations in test conditions or by introduction of tools made from different lots of the same brand. Likewise there is no assurance that test bars supplied prospective purchasers for a purely competitive test really represent the average product of various manufacturers. In many cases they do but in others a portion of the steel later supplied has been

below the standard. Unless suitable methods are employed to check subsequent shipments against performance in the competitive test the variations encountered may be much greater than the differences originally found between various steels.

Unless breakdown tests are made under conditions very closely approximating those of actual service the results obtained will mean little or nothing

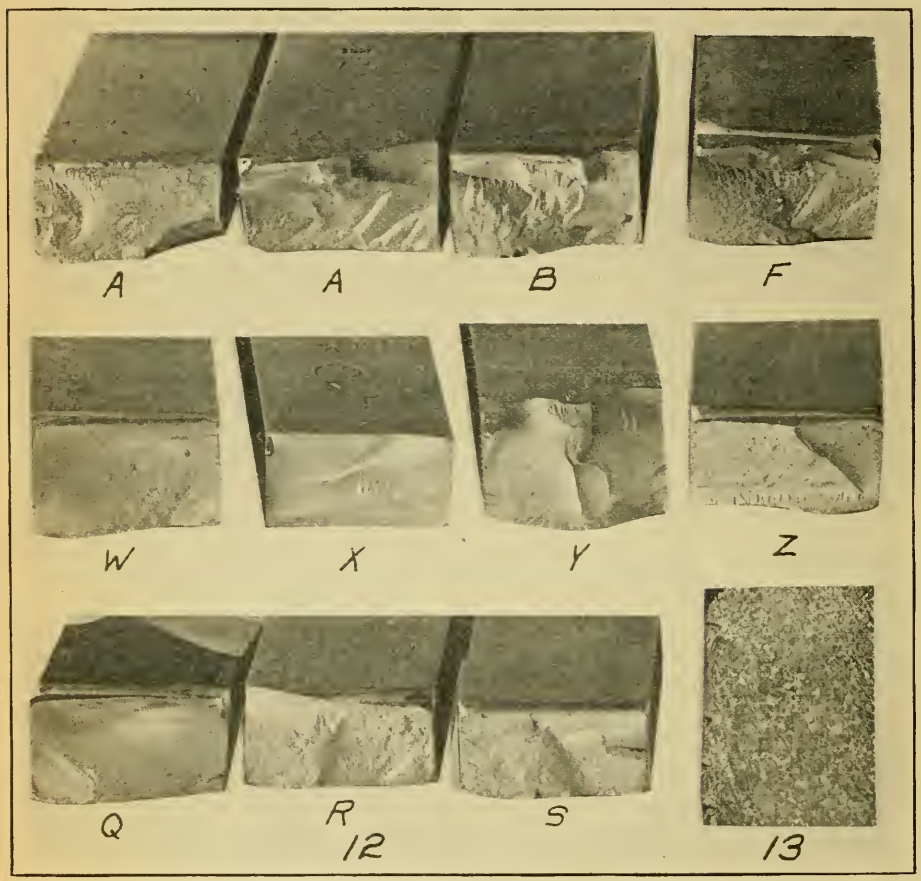
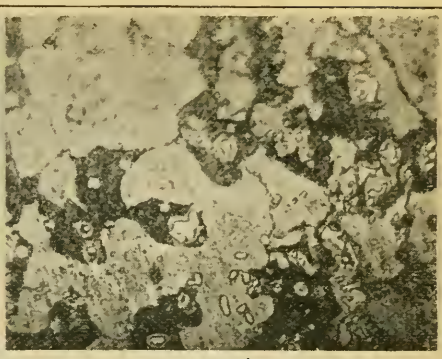


Fig. 12—Fractures of some of the lathe tools subjected to breakdown tests, about one-half size. Tools shown are those hardened over their entire length and used in test No. 3. Letters shown represent the various brands.

Fig. 13—"Fish scale" fracture in high speed tool steel. Note quenching and grinding cracks.

and may actually be misleading for, as previously shown, two types of steel may have comparable endurance under certain test conditions but if these are materially changed the endurance of one may become much greater than that of the other. Results of breakdown tests can only be accepted if a large number of tools are tested and the averages of at least two grinds are used in interpretation of results. They may therefore be employed to detect steel of highly qustionable quality or to differentiate between steels or groups of widely different performance, but are not satisfactory for competitive comparisons used as the basis of purchase. Rather would the authors recommend the purchase of definite types of high speed tool steel on the basis of price from

14 a



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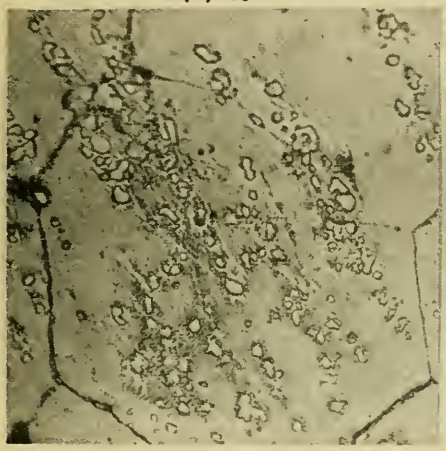

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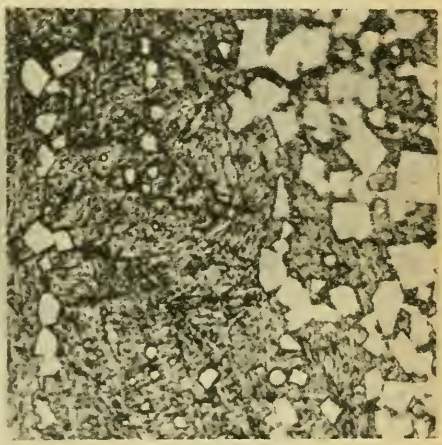

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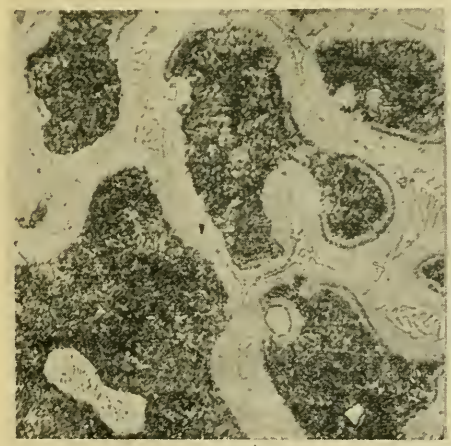

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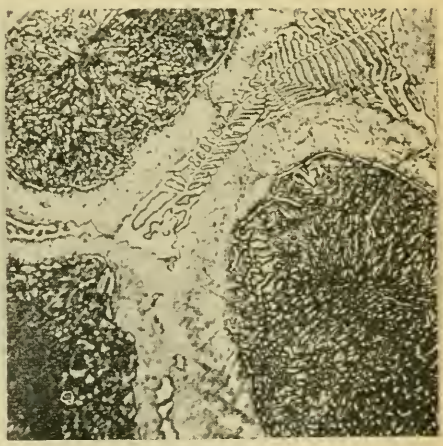

16

Fig. 14a—Characteristic structure of steel X. X 1000. Fig. 14b—Zone of partial melting observed in tool of steel S. X 500. Fig. 14c—Section near top surface of tool shown in 14b. X 500. Fig. 15a—Section of tool of steel S shown in Figs. 16b and 15c X 750. Fig. 15b—Surface of heat treated tool S showing effects of sweating. X 750. Fig. 16—Cast high tungsten-low vanadium high-speed steel for comparison with Fg. 16b. X 750.

manufacturers known to produce a uniformly high grade product and the use of suitable inspection tests to insure the quality of various shipments made. The establishment of a selected list of producers should not be objectionable for it would be open to all organizations able and willing to demonstrate high quality of product. Inspection tests might include macroscopic etching, fracture, chemical analysis and even microscopic examination and breakdown tests, the last mentioned to insure the performance of steel being equal or better than a carefully prescribed minimum which could first be established.

Summary and Conclusions

Important features developed or conclusions drawn from the described tests may be summarized as follows:

1. Breakdown tests, in which endurance of tools is determined under definite working conditions, are not satisfactory as the basis of purchase for high speed tool steels.
2. While competitive comparisons of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty providing sufficient tools are tested and averages of at least 2 grinds are used in interpretation of results.
3. In certain severe breakdown tests with roughing tools on 3 per cent nickel steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low tungsten-high vanadium and cobalt steels was superior to that of the high tungsten-low vanadium type and special steels containing about 1/4 per cent uranium or 3/4 per cent molybdenum. The average power consumption in all cases was practically the same so that this factor need not be introduced in comparisons which may be made on the basis of endurance of the tools.
4. Modification in test conditions including small changes in tool angles but principally changes in cutting speed more markedly affected the performance of steels containing cobalt or special elements such as uranium or molybdenum than that of the basic types (plain chromium-tungsten-vanadium steels).
5. The relatively poor endurance of the high tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than either the low or high tungsten steels.
6. Hardness determinations and examination of fractures indicate that the various types of commercial high speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions, and might counterbalance slight advantages in performance.

The authors take pleasure in making acknowledgement to Lt. Commander H. L. Merring, U. S. N. whose generous co-operation made it possible to carry out much of the work and assemble the test data described in this report, and to Mr. T. G. Digges, Asst. Physicist, Bureau of Standards, for valuable aid in carrying out many of the tests. Acknowledgement of assistance is also made to Mr. T. H. Johrden, Machinist Inspector and Mr. J. W. Talley, Asst. Chemist, of the U. S. Naval Gun Factory.

CARBURIZING AND DECARBURIZING IN CASE HARDENING

H. B. Knowlton

Abstract of Paper

This paper discusses the carburizing and decarburizing actions which make for the success or failure of the case hardening method in commercial practice. The following points are brought out. Successful case hardening must produce cases of the proper depth, per cent of carbon, and free from decarburization. The temperature of the lining of the furnace and the ratio of the weight of the charge to the weight of the lining are important factors determining the speed of heating. The use of test pins for determining the depth of case before removing the charge from the furnace, is recommended. The thickness of case on pieces of different sizes and shapes carburized together is shown.

The per cent of carbon in cases of the same depth may vary greatly. The carbon content is best estimated by use of the microscope. The temperature, pressure, method of packing, speed of cooling, and the nature of the carburizing material affect the per cent of carbon and the depth of penetration. Reference is made to Giolitti's experiments and his statement of laws governing carburization. The effect of uniform and nonuniform materials is shown.

Factors which may produce decarburization are discussed. Experiments are described showing the effect of different carburizing materials in poorly sealed pipes. Poor carburization and decarburization of pieces near the top but not uncovered, is shown. Effect of carburizing in well sealed box is shown. The use of strong carburizing materials and well sealed containers is advocated. The paper is illustrated with tables, photographs and photomicrographs.

THERE can be little doubt that the case hardening process, when properly carried out, can produce very desirable results. By this process, articles can be produced, which have the maximum surface hardness combined with the maximum internal toughness. However the process has its opponents, because of the numerous errors which may occur. It is the purpose of this paper to discuss some of the carburizing and decarburizing factors which tend to make for the success or failure of the case hardening process. In order to be successful the methods used must produce articles which have the proper depth of case, the proper per cent of carbon in the case, and which are free from surface decarburization.

Depth of Case

That an accurate control of the depth of case is necessary, needs little

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discussion. If the case is unnecessarily deep, particularly in pieces having thin sections, there is a sacrifice of toughness. On the other hand, if the case is too thin, it will not stand up in service. Yet in spite of the fact that the importance of the depth of case is universally recognized, one of the most common errors is inaccurate control of the depth of carburization.

In many places it is the practice to run the carburizing heat for a certain number of hours at a given temperature, and then remove the pots assuming that the proper depth of case has been produced. The temperature is usually judged by one or more thermocouples placed somewhere in the muffle of the furnace. These couples measure the temperature of the furnace gases and not the temperature of the inside of the carburizing pots or boxes. Providing the temperature of the inside of the boxes was actually maintained at a given degree for a certain number of hours, and the same kind of steel and the same carburizing material were used, the same depth of case should be produced on each run. But when the heat is run for a certain number of hours after loading or after the thermocouple in the muffle, records the desired temperature, constant results are not always obtained. This is due to the fact that the length of time consumed in heating the boxes entirely through is a variable depending upon a number of factors. The temperature indicated by the thermocouple does not tell the whole story.

For example, consider a furnace fired by gas or oil. The furnace gets its heat directly and indirectly from the burning of the gas or oil. Some of the combustion usually takes place in a combustion chamber outside of the muffle proper. The muffle of the furnace is filled with burning gases and hot waste gases. The major part of the heating is done by these gases. When the lining of the furnace is cold, the heat of these gases is absorbed in heating the lining and taking care of heat losses through the walls, doors, and flues. When the lining is thoroughly heated, the hot gases have to take care only of the heat losses. When a cold charge is placed in a hot furnace it absorbs heat from the lining and from the furnace gases. So when a cold charge is placed in a thoroughly heated furnace, the heat of the furnace gases is utilized solely in heating the charge and taking care of the heat losses, but when the furnace lining is cold or only partly heated, the heat of the furnace gases is used not only in heating the charge and taking care of losses, but part of it is used in heating the lining of the furnace. It is obvious that in the former case the charge will be heated more rapidly, assuming, of course, that the temperature and quantity of the furnace gases is the same in both cases. The thermocouple in the furnace, indicates only the temperature of the gases. Of course the temperature of these gases is affected by the temperature of the lining and the charge, but the temperature of the gases can not be accepted as a criterion for judging the temperature of either the lining or the charge. Radically different conditions with regard to the latter, may be represented by identical pyrometer readings. Again, even when the lining of the furnace is thoroughly heated through, the ratio of the weight of the charge to the weight of the furnace lining, is an important factor influencing the speed of heating of the charge. If one small pot is placed in a hot furnace, it will be heated through much faster than a number of pots of the same size in a smaller furnace, or even in the same furnace. And yet a comparison of the pyrometer readings might fail to show how great the difference in the speed of heating really is.

In some places it is customary to count the time of the carburizing heat, beginning with the time when the outside of the pots appear the color of the

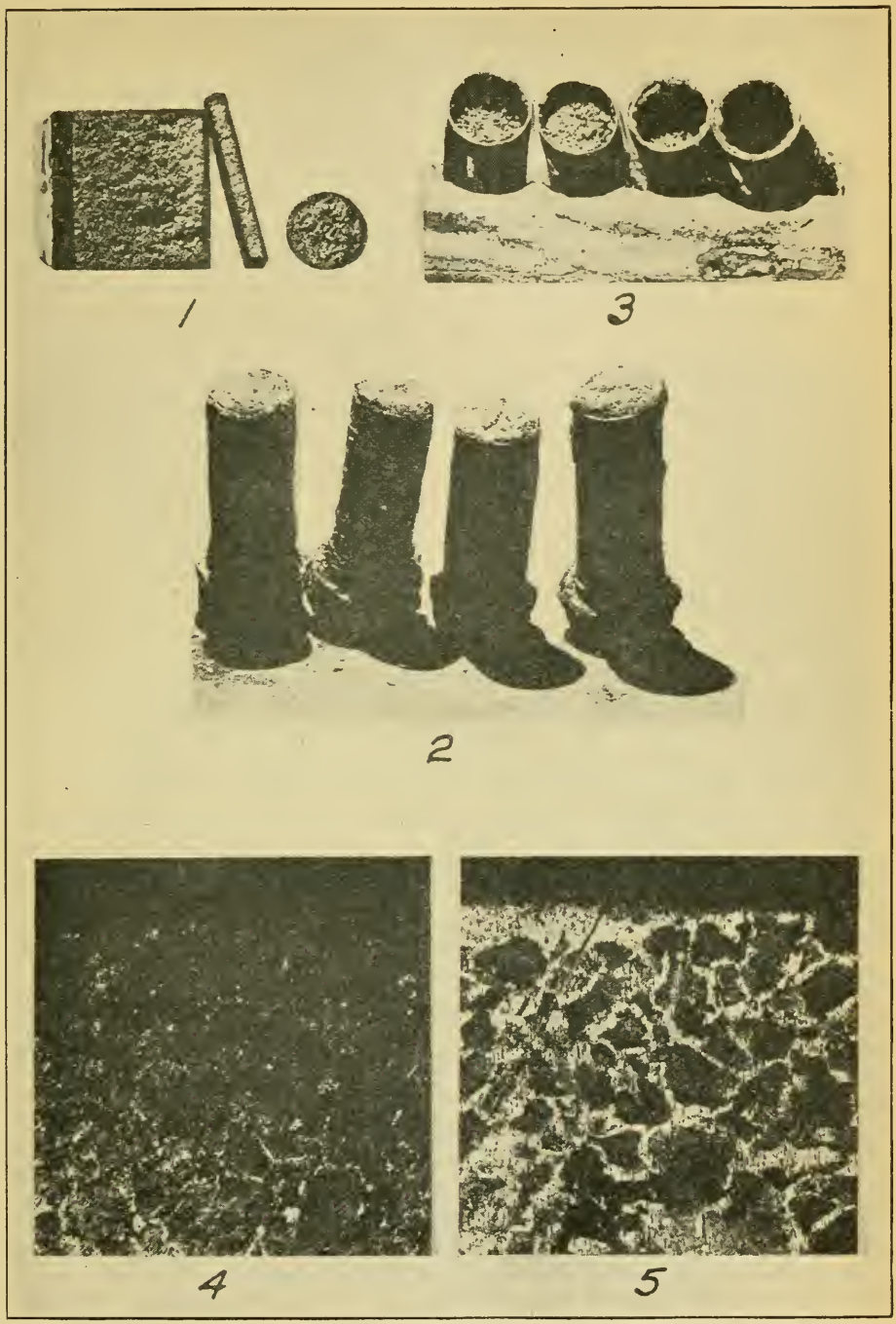

Fig. 1—Photograph of etched fractures of pieces carburized together. Note that the depth of case is the same on each. Fig. 2—Photograph of pipes at the end of the carburizing heat, showing the condition of the seals. Fig. 3—Photograph of pipes after removing the clay, showing the shrinkage. Fig. 4—Photomicrograph of bar in the center of pipe No. 1 containing mixed compound. X 150. Fig. 5—Photomicrograph of bar in the top of pipe No. 1 containing mixed compound. X 150.

thermocouple, and the latter records the desired temperature. This is better than starting from the time of charging, but it is not a safe way to judge when the center of the pots will reach the temperature. In some other hardening rooms it is the practice to withdraw a test bar from the center of one of the pots and judge by its color whether the inside of the pot has reached the temperature of the furnace. This is still better but is open to personal errors. Besides when the speed of heating is slow there may have been considerable carburizing before the inside of the pot reached the final carburizing temperature, while if the speed of heating was very rapid there would have been very little time for carburizing before the inside of the pot reached the final temperature. So this method may also be far from perfect.

Use of Test Pieces

A still better method is employed in some of the case hardening rooms. Several test pieces are laid up with each heat. When it is considered that the heat should be ready to come out, one of these test pieces is removed, hardened and broken, and the depth of the case is determined by examining the fractures. If the required depth of case has been reached, the heat is pulled. If not, the pot from which the test piece was taken, is sealed up again and returned to the furnace and the heat is run longer, until the test pieces show the proper depth of case. The objection which is often raised to this method, is that a small piece will not indicate the amount of case received by a larger piece in the same pot or box. It seems to be a common belief that thin pieces will acquire case much faster than thicker pieces in the same part of the same carburizing box. It is sometimes even stated that the thin section of a piece will be cased much deeper than the thick section of the same piece. A fracture or an etched cross-section of a carburized piece will show that this is not true. The inside edge of the case follows the profile of the piece, only rounding slightly at the corners. With regard to pieces of different sizes and shapes, which are near each other in the carburizing box, attention is invited to Fig. 1. This shows three pieces quite different in size and shape which were within an inch of each other in the carburizing box. As the box was allowed to cool before breaking the seal, it is obvious that the conditions of carburizing of each piece was the same. After carburizing the pieces were hardened broken and etched in nitric acid. The case shows black. It will be noted that the depth of the case is the same on all three pieces. Within reasonable limits it may be safely said that the depth of case on a small test piece may be taken as a criterion for judging the depth of case on the work in the same pot or box. The analysis of the steel must be the same in both cases, as alloys affect the speed of carburization.

In one large case hardening room this method has been employed for several years. Several test pieces are used in each heat. It has been found that about 95 per cent of the heats come out on scheduled time, but the saving of the other 5 per cent is worth the cost and trouble of using test pieces. Furthermore it has been found that heats are more liable to drag behind on Monday than any other day, due to the cooling of the furnaces over Sunday. It has also been found that the test pieces act as an early indication of trouble with the furnaces. As there are several test pieces in each heat, they show whether the furnaces are heating uniformly. When the baffles start to crack, the flues become plugged up, the pyrometers get out of order, or anything else happens to change the heating conditions, th test pieces indicate

that something is wrong.

Carbon Content of Case

One of the most important factors in case hardening is the per cent of carbon in the case. Unfortunately this can not be readily seen by examination of the fractures. The depth of the case may be the same in two pieces and if the hardening is good, the grain may be refined, and yet there may be considerable difference the per cent of carbon. It could not be expected that a case containing only 0.70 per cent carbon would have the same wearing qualities as one containing 1.00 per cent carbon. The scleroscope and the file test in commercial practice often fail to show the per cent of carbon. The microscope shows this very plainly, but unfortunately it is not used as much as it might be in commercial work. The amount of carbon at the surface will be affected by kind of carburizing material used, the temperature, the pressure, the method of packing, the speed of cooling, and sometimes the shape of the piece carburized. On slow cooling there is a tendency for the excess carbides if present to segregate at the surface. Where two or more surfaces come together to form an edge or a corner this tendency is increased, thus causing the carbon content at that locality to be very high. Quenching from the lowest possible hardening temperature does not change this, consequently pieces slowly cooled and single quenched are liable to be brittle at the edges and corners. A high quench prevents this condition.

Giolitti's book on cementation[1] is probably the most exhaustive and scientific treatise ever written on the subject. He shows that when the ordinary solid carburizing material is used that the carburizing action is due to the action of carbon monoxide or CO. He also shows that carburizing may be done with certain hydrocarbon gases. Other writers[2] have shown that cyanides, while they may add carbon to the steel, also add nitrogen, and that the hardness in the quenched pieces is due in part at least, to the nitrides formed. In this paper only the carburization due to the CO will be discussed, as this is the most common form of carburization, when solid carburizers are used. Based on his numerous determinations, Giolitti stated several laws which govern carburization by CO. He proved that the temperature, the pressure, and the quantity of CO all had an effect on the carburization. In practical work the temperature is governed to some extent by the effect of the temperature upon the steel. When the carburizing is done in pots or boxes, the amount of pressure obtainable is very limited. The amount of the carbon-monoxide gas, however can be controlled by the selection of the carburizing material. Giolitti stated: "All other conditions being equal, the concentration of carbon in the cemented zone increases when the quantity of pure carbon-monoxide which comes in contact with unit surface of the steel during cementation, increases." So anything which would increase the amount of CO should increase the concentration of carbon in the case. Of course the concentration of carbon in the steel can not be increased beyond the limit of solubility of carbon in the steel at the carburizing temperature. This probably explains why coke which may contain 80-90 per cent carbon, but which does not yield much gas on heating, and which burns slowly, is a poor carburizer, while bone and leather, which contain relatively small amounts of carbon, are good carburizers. However, both bone and leather wear out rapidly because the small amount of carbon present is quickly exhausted. Even with other types of carburizers there is a gradual

1. Cementation of Iron and Steel; Giolitti.
2. Brophy and Leiter; Trans. A.S.S.T. March, 1921.
   Ruder and Brophy; Chem. & Met. November, 1921.

change on use. The more easily volatile and combustible constituents are given off first. Many of the commercial and home made "compounds" contain certain chemical carbonates which are commonly called energizers. The function of these carbonates is to liberate carbon dioxide, which on coming in contact with excess amounts of hot charcoal, coke or other forms of carbon in the carburizing pot, is converted to carbon monoxide, thus increasing the quantity of carbon monoxide in the pot. The result is an increase of concentration of carbon in the case. That this is so, can be readily seen by compar-

TABLE I

Sixteen Specimens of S. A. E. 1020 Steel 1½ Inches Long by ⅜ Inches in Diameter Carburized for 3½ Hours at 1700 Degrees Fahr.

Carburizing Material used	Bar Number	Position in pipe	Depth of case in inches	Maximum carbon content at the surface
Pipe No. 1 Charcoal	1	Bottom	0.047	Less than 0.90 per cent
	2	5 inches from top	0.039	Less than 0.90 per cent
	3	3 inches from top	0.027	Less than 0.90 per cent
	4	1 inch from top	0.024	Very uneven 0.50—0.70 per cent
Pipe No. 2 All new Compound	5	Bottom	0.055	More than 0.90 per cent
	6	5 inches from top	0.055	More than 0.90 per cent
	7	3 inches from top	0.047	Slightly more than 0.90 per cent
	8	1 inch from top	0.051	About 0.90 per cent
Pipe No. 3 Soda ash in the bottom, Charcoal in the top	9	Bottom. In the chemical	0.01—0.039	Less than 0.90 per cent In some places very low
	10	5 inches from top In charcoal	0.043	Considerably Over 0.90 per cent
	11	3 inches from top	0.035	About 0.90 per cent
	12	1 inch from top	0.035	About 0.90 per cent
Pipe No. 4 Barium carbonate in the bottom, charcoal in the top.	13	Bottom. In the chemical	0.027 max.	Less than 0.90 per cent Uneven. In some places about 0.50
	14	5 inches from top in charcoal	0.039	About 0.90 per cent
	15	3 inches from top	0.031	About 0.90 per cent
	16	1 inch from top	0.027	About 0.90 per cent

ing the photomicrographs, Figs. 4 to 13 inclusive, of bars carburized in pure charcoal, with those of bars carburized under the same condition in a compound containing charcoal, coke, and chemical. One reason for the use of carbonates of the alkali and alkali-earth groups, is that these chemicals when exposed to air after use will reabsorb CO_2 from the atmosphere, and consequently they can be used over and over. On heating they give off CO_2, when

cold and exposed to air they absorb the same gas.

Uniformity of Results

That uniformity of results is desirable is axiomatic. In order to produce uniform results it is necessary that the carburizing material be uniformly mixed. In a recent test conducted by the author carburizing boxes were made from 2-inch wrought iron pipe. These containers were approximately 6 inches long with a pipe cap forming the bottom. One and one half inch test specimens ⅜ inch in diameter were prepared from S. A. E. 1020 steel. Four test specimens were packed into the box, one in the bottom surrounded by chemical, the next one an inch above the chemical and surrounded by charcoal, the third 2 inches above the second and the fourth 2 inches above the third. The 3 upper specimens were surrounded by charcoal. The top of the box was luted tight with clay. An air space of ¼ inch was made above the chemical in the bottom and the screen which separated the charcoal from the chemical. Another pipe contained a thoroughly mixed compound and the last pipe contained pure wood charcoal. Reference to Table 1 shows that the specimen in the charcoal directly above the chemical showed the deepest case and had the highest carbon content. Other specimens directly above this one in the same pipe showed decreasing amounts of carbon. This was due to the fact that nearly all of the gas liberated by the chemical in the bottom of the pipe and converted to CO on contact with the hot charcoal passed the first specimen, while only some of it reached the specimen at the top of the pipe. Thus the specimen near the bottom of the pipe came into contact with a larger quantity of gas than did the others and consequently it acquired a higher carbon content. It seems to the writer that this is a good and sufficient argument for a thoroughly mixed carburizing material, regardless of whether the mixing is done by the user or by an outside manufacturer.

Decarburization

One of the most common commercial troubles is that of soft spots due to decarburization. This may possibly occur during long reheating in an open furnace preparatory to hardening. If there is an excess of air in the reheating furnace there would be a tendency for the carbon to be burnt out of the surface of the steel. However the danger of decarburization in commercial work is probably less than might be supposed. Figs. 8, 9, 11 and 12 show the same specimens before and after reheating for 30 minutes at 1400 degrees Fahr. in an open furnace. It will be noted that no decarburization is apparent on the specimens which were reheated.

Sometimes, however, decarburization occurs during the carburizing heat. A good example of this was observed by the author in which a specimen was carburized in a pipe containing pure wood charcoal. The ends of the pipe were sealed with a mixture of fire clay and sand. After slow cooling from the carburizing heat the specimen was sectionalized, polished and observed under the microscope. A broad band of almost carbonless iron at the surface was observed, followed by a zone containing about 0.60-0.70 per cent carbon. This can only mean that the steel was first carburized and then decarburized. As the pipe lay in a horizontal position in the furnace and as this specimen was crosswise in the pipe it is possible that toward the last of the heat, the end of the specimen observed became uncovered and consequently exposed to furnace gases which leaked in through the seal. It is universally recognized that when the carburizing material burns down and leaves the top pieces in the container exposed, that these pieces are liable to

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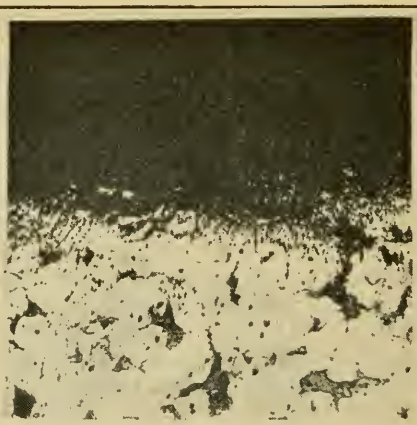

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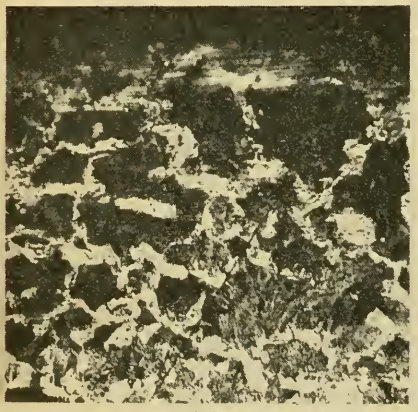

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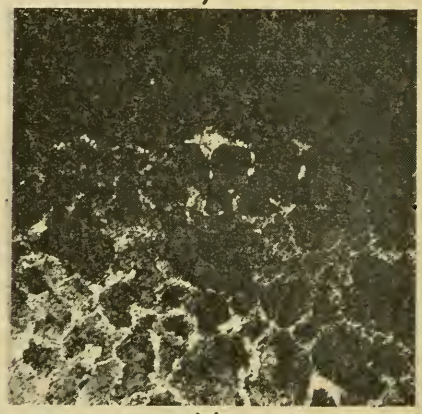

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Fig. 6—Photomicrograph of bar in the center of pipe No. 2 containing used compound. X 150. Fig. 7—Photomicrograph of bar in the top of pipe No. 2 containing used compound. X 150. Fig. 8—Photomicrograph of bar in the center of pipe No. 3 containing new compound. X 150. Fig. 9—Photomicrograph of same bar as in Fig. 8, reheated for 30 minutes in an open furnace. X 150. Fig. 10—Photomicrograph of bar in the top of pipe No. 3 containing new compound. X 150. Fig. 11—Photomicrograph of bar in the center of pipe No. 4 containing wood charcoal. X 150.

become decarburized. However, it does not seem to be so commonly appreciated that pieces very near the top, but not actually uncovered, may be decarburized or at least very poorly carburized. In discussing decarburization it may be well to refer again to Giolitti. He shows that carburizing takes place according to the reversible reaction: $2\ CO = CO_2 + C$. Thus when the conditions are right the CO decomposes yielding carbon to the steel. But under other conditions CO_2 may actually absorb carbon from the steel. For any set of conditions of temperature, pressure, and concentration of gases there is a concentration of carbon in the steel which is in equilibrium with the system. If the conditions in the first part of the carburizing heat favor a high concentration of carbon in the steel, and the conditions at the end of the heat favor a lower concentration of carbon, a decarburization at the end of the heat would be expected.

Toward the end of long carburizing heats particularly when the compound has burned down considerably and the seal is not very tight, we would expect that the gas at the top of the pot or box would be largely CO_2. This would have a decarburizing action. A commercial example of this came to the writer's attention a year or so ago. A certain firm was complaining of soft spots on their finished work. These soft spots were still in evidence after the routine grinding operation. However it was found that on the grinding operation, most of the stock had been removed from one side and only a little from the side where the soft spots appeared. After grinding under-size, the soft spots disappeared. This was plainly a case of decarburization following carburization. An examination of plant conditions showed that the carburizing was done in large square boxes which had no lids. The tops of the boxes were covered with a mixture of fire clay and sand. Some of the boxes had been used for a long time and had large holes in the sides. These holes were also plugged with clay. The carburizing heat was run at 1700 degrees Fahr. for 10-12 hours. It is believed that these conditions were responsible for the decarburization.

Test Heat Showing Carburizing and Decarburizing Tendencies

In the preparation of this paper a test heat was run to show the carburizing and decarburizing tendencies. The data obtained in this test is shown in Table II and the photomicrographs are shown in Figs. 4 to 13 inclusive. In this test, 4 different carburizing materials were used; a 2 and 1 mixture old and new "compound"; all old compound; all new compound; and pure wood charcoal. The containers consisted of four 2-inch pipes with caps screwed on the bottom. The test specimens were 8 pieces of ⅜ inch diameter S. A. E. 1020 steel which were rough ground to remove scale and rust. One test specimen was placed horizontally 3½ inches from the top of each pipe, that is in the center of the pipe. Another test pin was placed 1¼ inches from the top of each pipe. After loading, the pipes were sealed with a mixture of fire clay and sand moistened with brine. The pipes were placed vertically and as close together as practicable in the center of the heated furnace. At the conclusion of the run the furnace was shut down and the pipes were allowed to cool in the furnace. The condition of the pipes and the seals may be seen in Fig. 2. It will be noted that the seals appear to be in good condition. Fig. 3 shows the same pipes after removing the clay. The per cent of shrinkage is given in Table II. The test specimens were sectionalized, polished, etched, and photographed through the microscope. In each case the photomicrograph shows the edge of the cross-section, that is they show the structure of the steel at the surface and for

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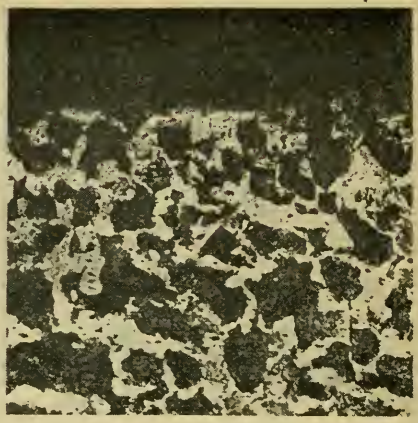

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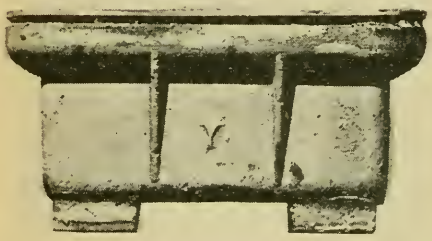

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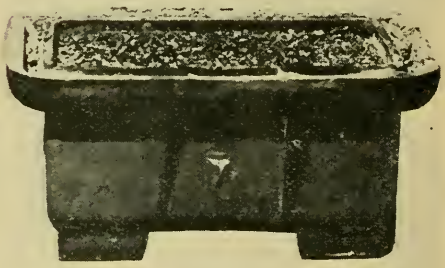

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Fig. 12—Photomicrograph of same bar as in Fig. 11 reheated for 30 minutes in an open furnace. X 150. Fig. 13—Photomicrograph of bar in the top of pipe No. 4 containing wood charcoal. X 150. Fig. 14—Photograph of carburizing box at the end of the heat. Fig. 15—Photograph of the same box after removing the lid. Note the small amount of shrinkage. Fig. 16—Photomicrograph showing the structure of bar carburized 1¼ inches from the top in the box.

about 0.01 inch below the surface.

Results

The data in Table II and the photomicrographs speak for themselves. It will be noted that the specimen in the center of each pipe shows a carbon content at the surface of eutectoid ratio or better, that is the carbon is 0.90 per cent or more. The specimen in the center of the pipe of new compound shows the highest carbon content being decidedly hyper-eutectoid. All of the specimens which were within 1¼ inches of the top of the pipes showed inferior carburization, being less than eutectoid ratio. All except the specimen in the top of the pipe of old material would harden fairly hard, and there

Table II

Data of Test Heat

Eight specimens of S.A.E. 1020 steel 1½ inches long by ⅜ inch in diameter rough ground and carburized for 6½ hours at 1700 degree Fahr.

Pipe No.	Contents	Shrinkage by Volume	Position of Test Piece	Carbon Content At Surface	Photo Micrograph Figure No.
1	2 parts old 1 part new Compound	14 per cent	3½ inches from top	Eutectoid	4
			1¼ inches from top	Less than eutectoid. Decarburized	5
2	All Used Compound	9 per cent	3½ inches from top	Eutectoid	6
			1¼ inches from top	Almost no carburization	7
3	All New Compound	21 per cent	3½ inches from top	Hypereutectoid	8
			1¼ inches from top	Less than eutectoid	10
4	All Wood Charcoal	34 per cent	3½ inches from top	Eutectoid	11
			1¼ inches from top	Less than eutectoid	13

fractures would indicate a "case." These might easily pass a commercial inspection, but they would really be very inferior. The specimen in the top of the pipe of old material showed but very little more carbon than in the original bar. The specimen in the top of the mixture showed a tendency to decarburization at some spots. The moral of this would seem to be, to use a strong carburizing material and to keep the top pieces well below the top of the carburizing material. Placing them so that they do not become uncovered during the heat, is evidently not sufficient. Use of all new "compound" of the type used in this experiment, is not recommended for ordinary work as it seems to produce an excess amount of carbon, which might not be desirable.

Test with Tightly Sealed Carburizing Box

In order to determine the effect of increasing the efficiency of the seal, another test was run, using a commercial carburizing box with a specially designed lid which could be sealed tightly. This was loaded with a mixture of one part old and one part compound (same compound as used in the previous experiment). A test specimen was again placed 1¼ inches from the top. The heat was maintained at 1700 degrees Fahr. for 6½ hours as before, and the box was allowed to cool in the furnace. The appearance of the box at the end of the heat is shown in Fig. 14. The appearance after removing the lid is

the heat is shown in Fig. 14. The appearance after removing the lid is shown in Fig. 15. It will be noted that the shrinkage is very much less, being about 6 per cent. The test specimen was sectionalized, polished, etched, and a photomicrograph taken at the edge of the cross section. This is shown in Fig. 16. There was a very thin layer of eutectoid composition at the surface. This does not show up as clearly as was hoped in the photograph, as the edge does not show up definitely. It may be considered therefore that this specimen is slightly better than those in the tops of the pipes. While the pyrometer record was very nearly the same in both cases, it is probable that the box being much heavier and thicker than the pipes, did not heat up nearly as fast as the pipes and consequently we could not expect as deep a case.

These tests were taken from a series of similar tests all of which seemed to follow the same general rule. It is believed therefore that the results may be taken as fairly indicative of the general principles and not merely as freak results.

Summary

Successful case hardening must produce a case of the proper depth, of the desired carbon content, and be free from decarburization. In order to be sure of producing the proper depth of case, it is recommended that a test piece be hardened and broken before pulling the heat. Carburization with solid materials is largely due to the action of CO. The concentration of carbon in the case, increases with the amount of CO. Carbon dioxide either inhibits carburization or causes decarburization. The conditions of carburization should favor as much CO and as little CO_2 as possible. Reheating in the open furnace if properly done should not cause excessive decarburization. All pieces to be carburized should be well below the surface of the carburizing material. Worn out or weak carburizers are not recommended. The carbon content is more easily estimated with the aid of the microscope than by examination of the fracture. Well sealed pots seem to be advantageous.

STUDY OF SOME FAILURES IN AIRCRAFT PLANE AND ENGINE PARTS

By J. B. Johnson and Samuel Daniels

This paper contains a compilation of several investigations made by the Material Section of the Engineering Division, Air Service, of breakages which have occurred in airplane and engine parts under service conditions. The investigation of failures is one of the most unsatisfactory duties of the testing engineer, as it is generally very difficult to determine definitely the cause of breakage. The conclusions which have been drawn were the best it was possible to deduce from the evidence submitted in the field reports and that obtained from the laboratory study of the broken specimens. Quite generally the history of the manufacture of the steel and the process of fabrication are not available, which adds to the complexity of the problem. There are, therefore, probably several points which are open to controversy, and it is hoped there will be free discussion of them.

The paper has been divided into three parts, each of which includes examples of failures which have been attributed to certain types of defects; but this classification is somewhat arbitrary, for often the investigation disclosed other contributing causes.

Part I

Failures Traceable to the Raw Materials

THE failures described in this section are attributed to improper selection of material or to defective steel which is generally caused by improper procedure in melting, casting, cropping, chipping, or other mill operations. Poor manufacturing practice leaves its mark commonly in the form of segregations, pipes, and seams, which are transmitted from the ingot or billet to the fabricated sheet, bar, or wire. Such defects decrease the available area of the stressed part and act as starting points for cracks in quenching, or determine at least in part the direction of the path of cracks, especially in a part subjected to vibration.

An example of the weakening influence of heavily segregated manganese sulphide is shown in Fig. 1, which represents a tachometer drive connection whose screw driver end was broken off in service. On the enlarged, roughly polished longitudinal microsection, Fig. 2, are lettered the fracture at *A*, and the transverse fissures *B*, *C*, and *D*. The annealed structure at the fracture was the same as that which existed at the borders of the transverse fissures. The steel contained 0.15 per cent of carbon and 0.114 per cent of sulphur, corresponding in composition to the S. A. E. screw-stock specification No. 1114. Examination of the unetched surface at fissure *D*, Fig. 3 clearly

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indicates that the cracks have followed the boundaries of manganese sulphide inclusions; and that when these particles were in the path of the progressing crack, they became more or less completely dislodged, with resultant widening of the breach. The stress which caused the failure was mainly torsional,

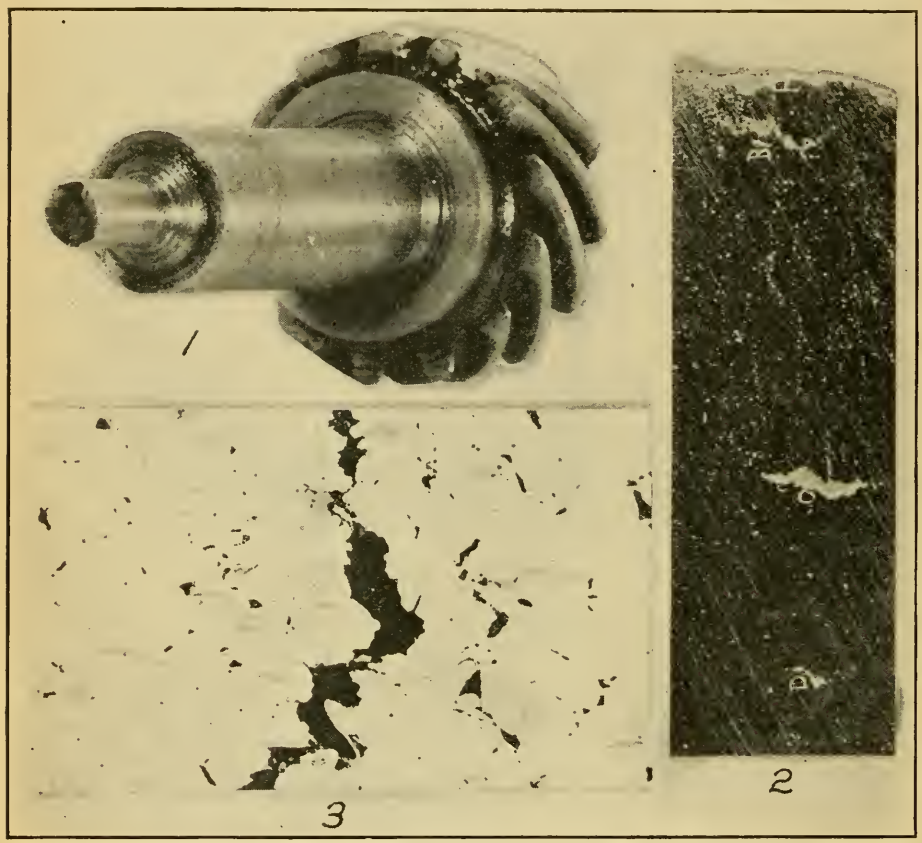


Fig. 1—Tachometer drive connection having failed in service. Fig. 2—Enlarged microsection of roughly polished portion of ruptured drive. Fractures are indicated as A, B, C and D. X 2. Fig. 3—Manganese sulphide inclusions responsible for failure of this component. X 100.

operating against the friction and especially the inertia of the tachometer and the flexible shafting when the engine speed was rapidly increased. The use of screw stock in such a part was not justified, and when S. A. E. steel No. 1020 was substituted the results were satisfactory.

Figs. 4, 5, 6 and 7 illustrate the extremely dangerous condition which resulted from the presence of a pipe in a forging billet. Fig. 4 is the transverse section, after light coarse-etching, of a pipe in a silico-manganese forged steel propeller, the analysis of which follows:

Carbon	0.55	per cent
Manganese	0.78	per cent
Sulphur	0.020	per cent
Phosphorus	0.016	per cent
Silicon	2.40	per cent

The structure was that of an annealed forging. A few surface cracks, caused by improper forging practice, had been filled with welding material and filed

smooth. The propeller broke in a whirling test, although the stresses were not excessive.

The transverse section of a piped clevis connection, Fig. 5, is to be seen in Fig. 6. This material passed the chemical and physical test requirements for cold-rolled S. A. E. steel No. 2330. The bar stock was machined into fittings. Later, when these were assembled in the airplane and the drift wires tightened in rigging the fuselage, one of the clevises broke. Other clevises

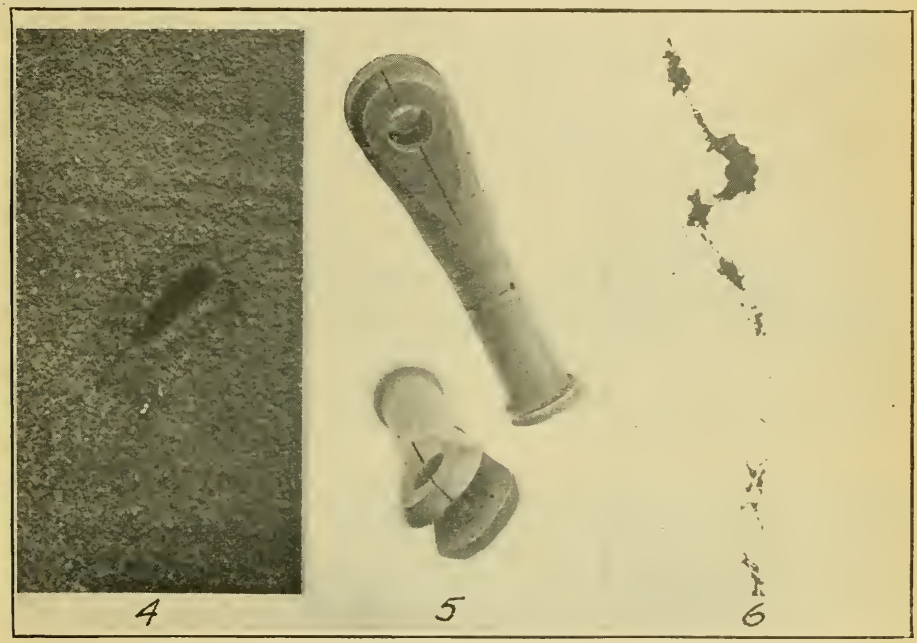


Fig. 4—Transverse section, after light deep-etching, of a piped silico-manganese forged steel propeller. X 2. Fig. 5—Rigging clevises which showed piping condition. Fig. 6 Pipe observed in clevises shown in Fig. 5. X 50.

from the same lot of material were immediately given a proof load test by applying 50 per cent of their rated load. In this test several of the clevises which had previously passed inspection, split longitudinally in tension, from the top of the clevis down through the eye.

Fig. 7, shows a valve which had been hand-forged from S. A. E. W-60a (high tungsten) steel. The stem of this valve had snapped off in service at the neck of the tulip, revealing a very spongy core, somewhat off center. Two longitudinal sections were prepared so that the one included most of the spongy area, and the other the sound portion. Upon coarse-etching the former and a piece of the stem in a boiling solution of 20 per cent aqueous sulphuric acid, the honeycomb through the neck and stem was brought out (Fig. 7, left), and in addition the discontinuity on both sides of the ring. The other half of the valve head was then etched in Humfrey's reagent (10 per cent cuprammonium chloride, 16 per cent concentrated hydrochloric acid, and 74 per cent of water (all by weight), for 75 minutes, after which immersion the section was freed from copper and then brightened by rubbing with 0000 emery paper. This etch also brought out the discontinuity (Fig. 7, right), the exact nature of which was not determined. One micro-section was

[1] Humfrey—Macro-etching and Macro-printing, Journ. Iron & Steel Inst.—1919, p. 273.

taken to include the break in macrostructure in this valve and another from the corresponding location in a tulip valve of like analysis which showed no differential attack in coarse-etching. It was impossible to detect great differences in microstructure between valves or on either side of the break. The structure of the neck side of the discontinuity is shown at 100 and at 1000 diameters in Fig. 8 and 9, respectively. In the latter metallograph an inclusion is to be seen, in addition to the undissolved carbides.

Pipes, practically closed up by the forging operation, were also found in a stainless, (S. A. E. 51230) high chrome steel valve as shown in Fig. 10.

Fig. 7—High tungsten steel valve showing a spongy condition after deep-etching. X 0.9.

This valve was very unsound and snapped off abruptly at the neck, while in service.

The Air Service has had considerable trouble with seams in chrome-vanadium steel wire used for valve springs. A transverse section of one of these wires, revealing a seam whose width was one-third the diameter of the wire, is shown, Fig. 11. The partial analysis of this material follows:

Carbon	0.48 per cent
Chromium	1.02 per cent
Vanadium	0.15 per cent

The effect of the seam is augmented considerably by improper heat treatment. Such wire, incorrectly drawn, as indicated in Fig. 12, lasted only a few hours under repeated torsional stresses in the springs; but drawing at the higher temperature of 700 degrees Fahr., produced the structure shown in Fig. 13, with the result that the springs gave much better service. Their use, however, was limited to ground tests, and then only in case of emergency.

Part II

Failures Traceable to Poor Machining or to Design

The effect of such mechanical imperfections in the finished part such as tool marks, nicks, and sharp corners, is analogous to the effect from segregation of inclusions, pipes, and seams, inasmuch as they may be the starting points of hardening cracks or fatigue failures. The finest grade of crucible steel may reach the scrap pile by way of poor methods of machining.

Figs. 14, 15 and 16, show three clevises which failed in service. These connections carried the tension load of a vibrating wire. The failures occurred under normal flight conditions in airplanes which had been flown for a con-

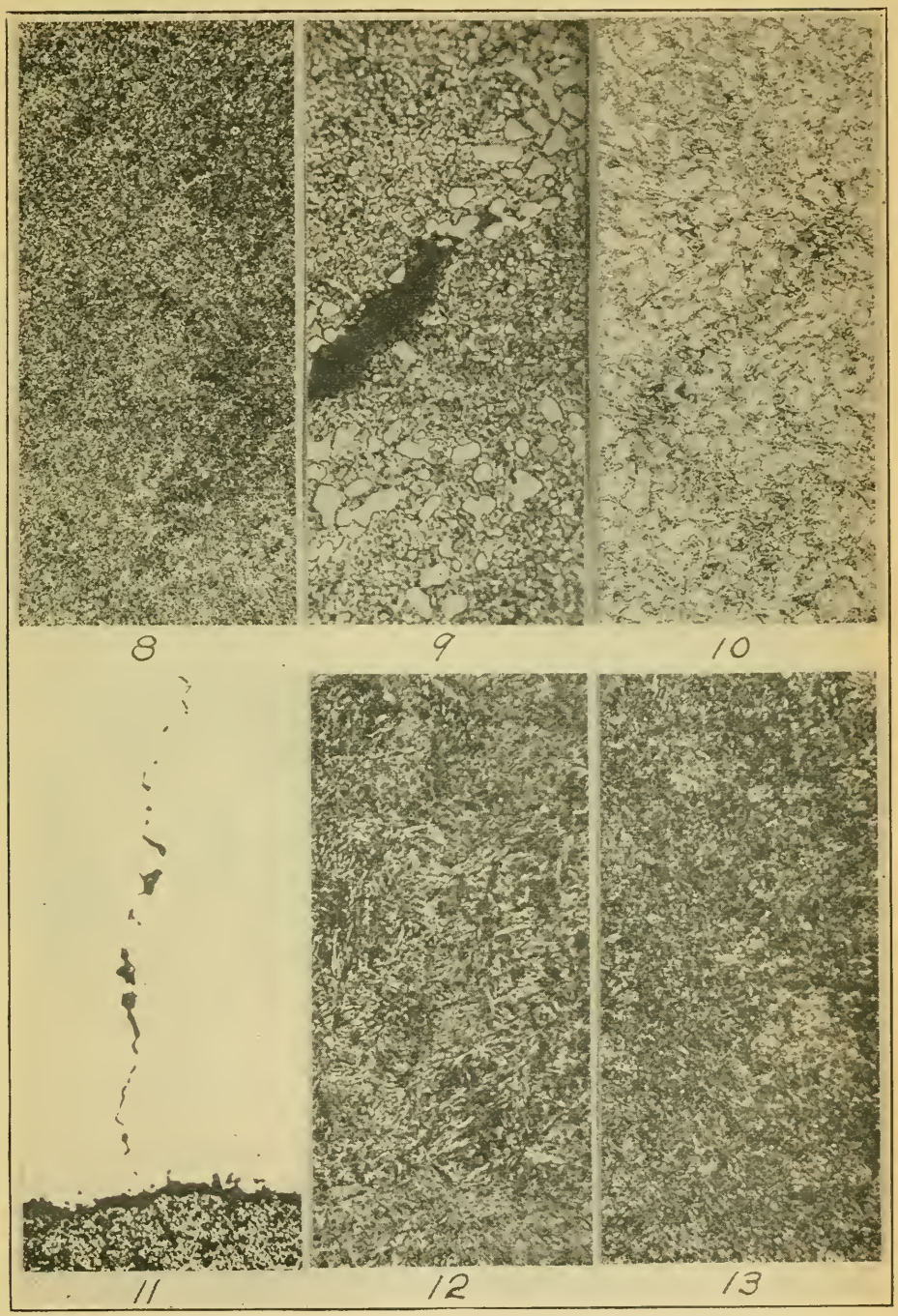
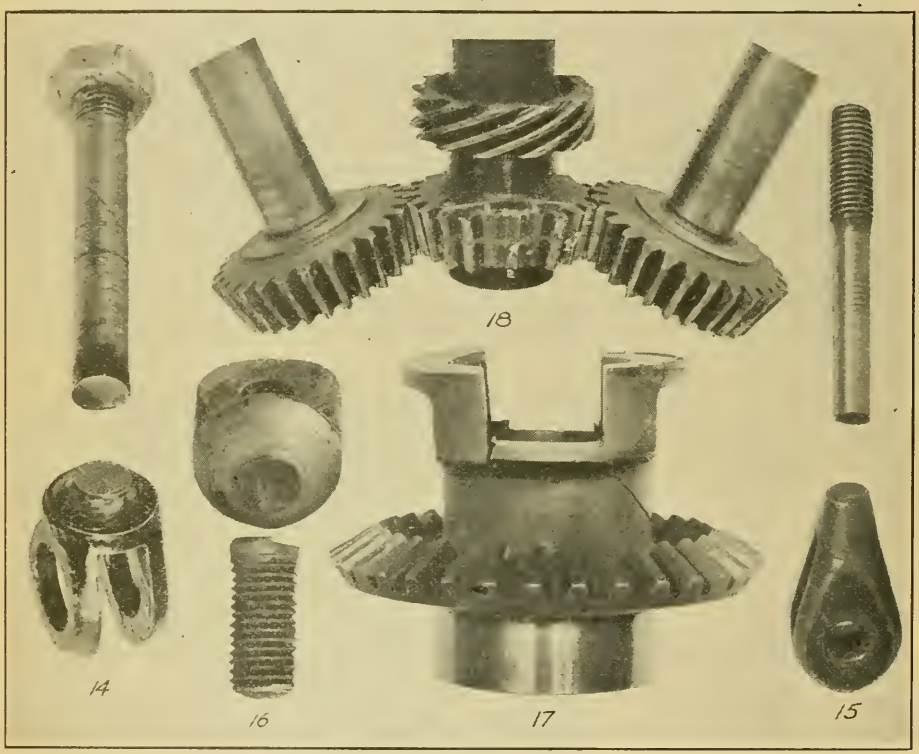


Fig. 8—High tungsten valve of Fig. 7. X 100. Fig. 9—Same valve at X 1000 showing undissolved carbide and non-metallic inclusion. Fig. 10—Stainless steel valve showing closed in pipe. X 11. Fig. 11—Seam which extended 1/3 thru Cr-Va valve spring wire. X 500. Fig. 12—Structure of same wire after improper drawing temp. X 500. Fig. 13—Same wire after proper drawing temp. X 500.

siderable period of time. Fracture developed at a point at the clevis end of the shank where the cross-section changed with only minor filleting and where there were deep tool marks, some of which are evident at other places along the shank. The steel in each case was found to be S. A. E. No. 2330 stock. The physical properties of the bolt were entirely satisfactory.

Ultimate strength, lb. per sq. in.	114,000
Yield point, lb. per sq. in.	101,000
Elongation in 2 in., per cent	22
Reduction of area, per cent	68.8

The results of a static tension test on ductile material are not influenced greatly



Figs. 14, 15 and 16 show three clevises which failed in service. These connections carried the tension load of a vibrating wire. Fractures developed at a point at the clevis end of the shank where the cross-section changed with only minor filleting and where there were deep tool marks. Fig. 17—Photograph of a failed crankshaft gear and starter coupling having sharp corners. Fig. 18—Gear failure which resulted from improper heat treatment and machining.

by small notches, but their effect on fatigue or shock resistance is considerable.

Sharp corners, too, are prolific as starting points for failures. In Fig. 17, is shown a photograph of a crankshaft gear and starter coupling manufactured from S. A. E. No. 2340 steel bar stock, the analysis of which is as follows:

Carbon	0.40 per cent
Sulphur	0.022 per cent
Nickel	3.61 per cent
Chromium	Nil

The coupling is subjected to considerable shock and must be hard. The

Brinell hardness of this part, taken near the fracture, was 555 and the scleroscope 65. The question arose as to whether the absence of proper filleting, or, in the light of experience with other gears not subjected to like shock, the abnormal hardness of the part was more important in causing the rupture. Exactly the same situation obtained with a Liberty crankshaft gear of S. A. E. No. 2340 steel, but of a Brinell hardness of 600. That a nickel steel is suitable for these parts is controvertible; and in fact, S. A. E. No. 3240 steel was recommended, as this steel will give greater ductility and shock resistance than the No. 2340 steel for the same Brinell hardness. The Brinell hardness range specified for the ordinary run of gears is from 400 to 440, and these

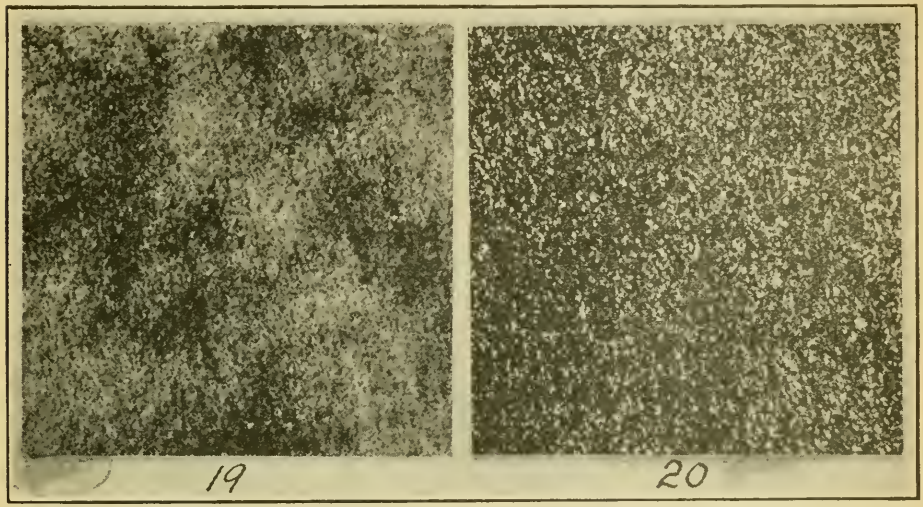


Fig. 19—Photomicrograph of banded structure observed in the ruptured gear of Fig. 18. Fig. 20—Photomicrograph showing homogeneous structure resulting from a proper treatment of gear shown in Fig. 19. Both photomicrographs. X 100.

limits were tentatively set for the gear parts described above, with the additional requirement of fillets at least one-sixteenth inch in radius.

Part III

Failures Traceable to Improper Heat Treatment

The number of failures directly attributable to improper heat treatment has been increasing rapidly. Disregard for the laws commonly adhered to in scientific metallurgical control and neglect to accurately follow the specifications given, have often resulted in unsatisfactory contract work. The situation has led to much closer supervision, during the heat treatment, by the Air Service inspectors.

The train of gears shown in Fig. 18, failed before the completion of a 50-hour dynamometer test run. The chemical analysis of the central camshaft driving pinion was as follows:

C .35, Mn .58, S .042, P .006, Cr 1.04, Va .23.

The Brinell hardness of this part was 402. Examination revealed that sharp corners existed at the roots of the teeth. Despite the fact that the Brinell hardness was suitable, and that no fillets had been provided, the principal reason for the failure was attached to improper heat treatment. The banded structure of Fig. 19, taken of the gear as received, has been frequently observed in failed gears of this analysis; but no failures have yet been recorded of gears treated to the homogeneous structure represented in Fig. 20, which

was obtained by soaking the banded specimen for 30 minutes at 1675 degrees Fahr. and quenching in oil, followed by a draw at 650 degrees Fahr. in a nitrate bath.

An examination of a broken propeller hub cap which had failed in service, illustrated the effect of improper structure. This component is a hollow cylindrical piece machined from a hot-pierced forging of S. A. E. No. 1045 steel.

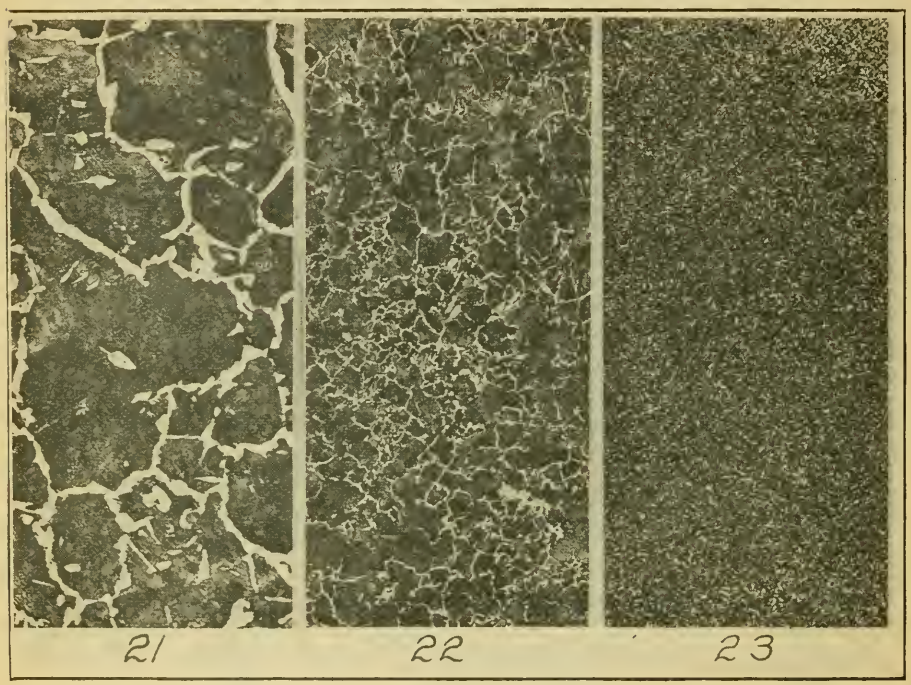


Fig. 21—Photomicrograph of broken propeller hub cap which failed in service. This coarse-grained hypoeutectoid structure has poor resistance to shock. Figs. 22 and 23—Photomicrographs of the same material shown in Fig. 21, heat treated to obtain increased impact resistance. X 100.

The primary stresses in service are tension and compression exerted by the centrifugal force of the blades, and bending caused by thrust. The loads are suddenly applied by rapid acceleration of the engine. The microsection from the broken cap revealed a coarse-grained hypoeutectoid structure similar to that in Fig. 21. Tension test specimens cut from the broken hub gave the following results:

Ultimate strength, lb. per sq. in.	97,630
Yield point, lb. per sq. in.	59,800
Elongation in 2 in., per cent	19.2

Another hub cap from the same lot was then selected for the purpose of improving its shock-resisting qualities, which were believed to be low, even in the light of the rather good tensile properties developed by the first forging tested. The properties of the steel for the heat treatments selected for trial

are given in Table I. On account of the marked increase in impact resistance which it produces in the steel, the treatment prescribing quenching and drawing was recommended for the part and has been used successfully. The metallographs (Fig. 21, 22 and 23) illustrate clearly the changes in grain size and structure which accompanied the marked improvement in yield point, ductility, and impact resistance.

A hardening crack, which started in a sharp corner, was the cause of failure of an improperly heat treated master connecting rod which came

Table I

Physical Properties Resulting from Different Thermal Treatments

Structure	As forged Sorbite plus ferrite network	Annealed* Sorbite plus ferrite network	Quenched and drawn** Sorbite
Ultimate strength, lb./sq. in.	99,260	107,720	100,830
Yield point, lb./sq. in.	41,760	60,610	84,710
Elongation in 2 in., per cent	19.5	21	26
Reduction area, per cent	30.8	44	61.7
Brinell	192	211	207
Scleroscope	31	35	35
Izod impact (V notch)	2.3	12.5	43.3
Charpy impact (round notch)	7.8	11.5	50.2

* Soaked at 1525 degrees Fahr. for 20 minutes and cooled in air.

** Soaked at 1525 degrees Fahr. for 20 minutes, quenched in water, and drawn at 1200 degrees Fahr.

Chemical Analysis

Carbon	0.52 per cent
Manganese	0.58 per cent
Phosphorus	0.032 per cent
Sulphur	0.026 per cent

under observation. The rod had run about 100 hours with the engine operating at normal horsepower. The smooth, fan-shaped fracture, proceeding from the sharp corner, indicated that this portion was progressively opened up by fatigue stresses; while the fibrous condition beyond marked the plane of ultimate rupture induced by both shear and bending forces. The chemical analysis was normal for an S. A. E. No. 6135 steel:

Carbon	0.35 per cent
Manganese	0.59 per cent
Sulphur	0.022 per cent
Phosphorus	0.030 per cent
Chromium	0.86 per cent
Vanadium	0.13 per cent

The average Brinell hardness of 230 was somewhat lower than the value obtained in properly treated connecting rods. Heterogeneity of metallographic structure, evident in Figs. 25 and 26, is the result of different rates of cooling in the heavier section (crank end) at the fracture, and in the web of the lighter I-beam section (piston-pin end), respectively. Both structures are very finely sorbitic, with free ferrite, the latter constituent being more abundant at the fracture, where the rate of cooling was slower. These structures are typical of air-cooling from above the critical range. It was found impossible to duplicate either structure in a specimen which was oil quenched from 1650 degrees Fahr., reheated to 1350 degrees Fahr., and air-cooled. It seemed probable that after forging, the connecting rod was quenched in oil from about 1650 degrees Fahr., and then air-cooled at a temperature approximating 1475 degrees Fahr., thus accounting for the fine grain size of the

material (Fig. 24). The proper structure for this part, obtained by quenching from 1650 degrees Fahr. in oil and drawing at 1140 degrees Fahr., following normalizing and annealing, is shown at 1000 diameters in Fig. 27. It was suggested that a change in design be made to include ample fillets, thus to lessen the danger of hardening cracks and the localization of fatigue stresses.

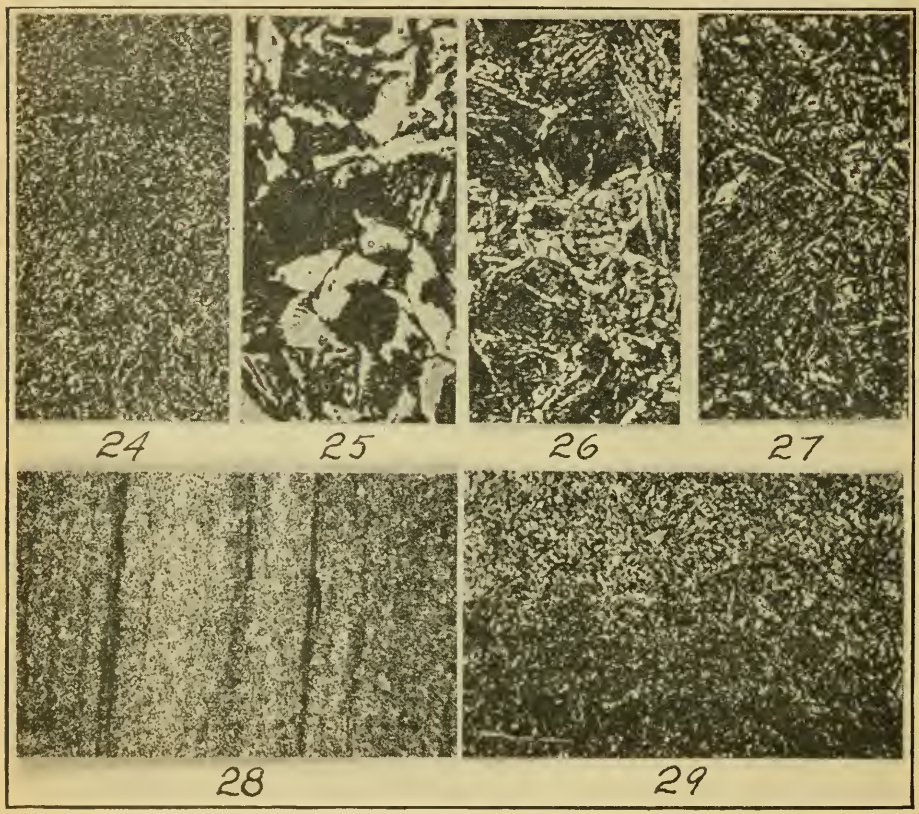


Fig. 24—Photomicrograph of connecting rod quenched in oil from 1650 degrees Fahr. and air cooled from a temperature of 1475 degrees Fahr., thus accounting for the fine grain size. X 100. Figs. 25 and 26—Heterogenity of metallographic structure resulting from different rates of cooling connecting rod. Fig. 25 shows the structure in the heavier section (crank end). X 1000. Fig. 26 shows the structure in the thin section (piston-pin end). X 1000. Fig. 27—Photomicrograph at 1000 diameters showing the proper structure for this component when quenched in oil from 1650 degrees Fahr. and drawn at 1140 degrees Fahr.

Fig. 28—Photomicrograph of ghost-lines present in ruptured valve springs. Several of these springs failed to withstand a 180-degree bend test. X 100. Fig. 29—Photomicrograph at 1000 diameters showing a sorbo-troostitic structure.

In another case a number of valve springs broke in a service run. The analysis was found to be the following:

Carbon	0.52	per cent
Manganese	0.96	per cent
Sulphur	0.025	per cent
Phosphorus	less than 0.030	per cent
Chromium	1.30	per cent
Vanadium	0.28	per cent

Several of the springs failed to withstand a 180-degree reverse bend, and

(*Continued on page* 1212)

IRREGULARITIES IN CASE HARDENED WORK CAUSED BY IMPROPERLY MADE STEEL

By E. W. Ehn

Abstract of Paper

1. *Failure in case-hardening, especially in reference to soft spots, is often due to improper steel. Variation of structure of a carburized piece gives a direct indication whether the steel is suitable for carburizing or not.*

2. *Coarse-grained structure in case and core of carburized steel with large crystals of pearlite, and clean cut cementite areas in the hyper-eutectoid zone, are signs of good or normal steel. Curly cementite, disintegration of pearlite in hyper-eutectoid zone, and fine-grain size with rounded pearlite areas in the gradation zone and core are signs of an abnormal steel. Abnormal steel has a tendency to give a thin case of high-carbon content and to form soft troostitic spots in hardening.*

3. *The structure of normal and abnormal steel varies with the carburizing temperature and the rate of cooling. Carburizing tests on a laboratory scale can easily be made.*

4. *The variation in carburizing properties is caused by oxides uniformly distributed in solid solution in the steel. The ultimate cause is improper deoxidation of the steel when made, and no later treatment can change these properties.*

5. *The influence of the oxides in regard to grain size is theoretically explained by their influence on the solidification of the steel in the ingot and their later obstructing action against grain growth. Disintegration of the pearlite in the hyper-eutectoid zone is caused by the solution pressure from the oxides in solution in the ferrite.*

6. *The formation of soft troostitic spots in hardening of abnormal steel is explained by the action of the oxide particles as starting points for the troostite formation. This explanation is founded on the investigations of Portevin and Garvin on hardening of carbon steels.*

7. *The results obtained in heat treatment of all kinds of steels, notably high and medium carbon steel, is dependent on the presence of oxides in the steel, and many mysterious failures, especially in hardening, are likely to find their explanation by carburizing; and a microscopical examination of the structures obtained.*

The experiences given in this paper are the results of considerable research work during the last few years in the Metallurgical Department of The Timken Roller Bearing Company. Most of these results have already been published (H. W. McQuaid and E. W. Ehn "Effect of Quality of Steel on Case Carburizing Results"—American Society of Mining & Metallurgical Engineers, February, 1922, and E. W. Ehn—"Influence of Dissolved Oxides on Carburizing and Hardening Qualities of Steel"—Iron & Steel Institute, May, 1922), and it was only after request from the Publication Committee for the Detroit convention meeting of the American Society for Steel Treating that the present paper was prepared. This remark is made because the writer wants it understood that he has drawn freely on the previous papers and that this paper does not contain any materially new information, although a few new experiences are included.

A paper to be presented before the Detroit Convention October 2-7. The Author E. W. Ehn is metallurgist, Timken Roller Bearing Co., Canton, Ohio.

Introduction

IN CARBURIZING steels of similar chemical compositions, similar results are generally expected and if the carburizing and hardening are properly conducted, satisfactory results are anticipated. This paper will show that the quality of steel when made, has a very material influence on the results obtained in carburizing and hardening, and that satisfactory results can only be obtained with carefully made and deoxidized steel. The trouble experienced with inferior grades of steel are mainly the occurrence of soft spots after the hardening operation and sometimes, although comparatively seldom and only in the worst types of steel, shallow and uneven carbon penetration resulting from the carburizing process.

The paper will, unless otherwise stated, deal with steel of the following composition:

Carbon	.15 to .20 per cent
Manganese	.35 to .65 per cent
Phosphorus	below .040 per cent
Sulphur	below .040 per cent
Silicon	.05 to .20 per cent

It will be shown that some steels although in accordance with this analysis, which can be regarded as a standard for plain carbon steel for carburizing, are entirely unsuitable for carburized parts and cannot be used without grave danger of inferior results. This is, moreover, not only a question of theoretical interest but a matter of great commercial concern, as this condition in steel is far more common than is usually suspected. In the plant with which the writer is connected hundreds of tons of steel have had to be diverted to other purposes than carburizing and thousands of dollars worth of half finished work scrapped owing to failure in hardening. It can be said that as a rough estimate about 25 per cent of all steel bought in the open market has been found to be unsuitable for carburizing and it has been found necessary to institute very careful checking of every heat of steel before allowing it to be used for production.

The plant with which the writer is connected is the maker of tapered roller bearings. In making of the different parts of these bearings, which are all made of case-hardened low carbon steel with and without alloying elements, depending on the service they will be exposed to, it is of utmost importance that uniformity in depth of case and hardness be obtained. In the hardening department of this plant it would occasionally happen, in spite of extreme care in the different operations, that a large amount of carburized work would fail to harden properly and had to be rejected on account of soft troostitic spots. These failures were at first attributed to faulty carburizing or hardening practice, but after considerable research work it was definitely proved, that the cause was due to some inherent property in the steel itself. The failures in the hardening were always traced to certain lots, while other lots that had simultaneously undergone the same processes gave no trouble whatever. Different carburizing compounds and different methods of quenching were tried, but failed to improve the results, and by gradually working back through the different stages of conversion of the steel, it was finally proved that the carburizing and hardening qualities of the steel were inherent in the ingot itself, and remained unchanged in any way by different operations in the course of manufacture.

It was also found that this feature of soft spots in the case hardened

steel was always combined with a special fine grained structure in the carburized parts. Steels which on hardening in water acquire a uniformly hard martensitic case will in what follows, be referred to as normal, whereas steel giving soft spots in the hardening will be called abnormal.

Part I

Microstructure and Properties of Normal and Abnormal Steel Observed Under Operating Conditions

The carburizing referred to in this part have been done in hydro carbonated bone-black at 1675 to 1700 degrees Fahr. followed by a cooling of the pots in the air. The carburizing compound used is, however, of no material importance except in relation to the maximum carbon content that it will transmit to the carburized pieces, and in order to develop clearly the difference in micro-structure between normal and abnormal steel, it is desirable that the carbon content of the hyper-eutectoid zone be 1.05 per cent or more. The hydro carbonated bone-black is a comparatively slow compound and so blended that a case of eutectoid or slightly hyper-eutectoid composition is obtained at least in case of less than 0.040 inch in depth. Most of the photomicrographs are therefore taken from samples with greater depth of case or in some cases from specimens that purposely have been carburized in more energetic compounds in order to conform with this condition.

A microscopical examination of carburized work reveals a large number of different types of micro-structures usually fairly uniform in parts made of steel from the same lot but varying greatly with different lots. Figs. 1 and 2 show typical structures of normal and abnormal steel after carburizing. The first steel will harden without difficulty and give a uniformily hard martensitic case, whereas the other is likely to give soft troostitic spots in hardening. The characteristics of the different structures of the different parts of the case will be better understood from separate photomicrographs at higher magnification taken from specimens other than those that were used in Figs. 1 and 2.

Extreme Cases of Normal and Abnormal Steels

Hyper-Eutectoid Zone.—Figs. 3 and 4 show the extreme types of normal and abnormal steel. In the normal steel the hyper-eutectoid zone (Fig. 3) consists of pearlite and free cementite sharply defined at the grain boundaries or lying as needles throughout the mass of the crystals. The grains are generally large and sharp-cornered in outline. The hyper-eutectoid zone of very abnormal steel (Fig. 4) consists of pearlite, cementite, and free ferrite. The cementite lies as small curly fragments in a mass of ferrite formed by the more or less complete divorce of the pearlite. The outlines of the crystals are not well defined, they do not follow straight lines, and the crystal size is small as compared with the normal steel. In order to develop this structure clearly it is necessary that excess cementite be present, the more the better, and the most pronounced types of this structure are therefore obtained in the corners of the specimens, where an almost complete divorce of the pearlite can sometimes be obtained.

Eutectoid Zone.—The difference is, at least in commercial steels, not very pronounced, but some cases have been observed where the abnormal steel shows a somewhat "fiery" appearance, with a more coarsely lamellar

pearlite than in the normal steel.

Gradation Zone.—The structure in the gradation zone is very sensitive to any variation in the steel, and the difference in structures obtained is even more pronounced than in the hyper-eutectoid zone. This is especially important in an eutectoid case, where the absence of excess cementite prevents the formation of the typical structure of the hyper-eutectoid zone, although it must be noted, that the structure of the gradation zone is more dependent on the carburizing temperature and the rate of cooling than that of the hyper-eutectoid zone. The normal structure in the gradation zone (Fig. 5) is considered as triangular or at least sharp-cornered areas of pearlite with sides not less than ½ inch at 100 diameters magnification and separated by clearly defined ferrite lines. The abnormal structure (Fig. 6) consists of rounded, not so well defined, and much smaller areas of pearlite often located in a streaky way. Between these two extreme types all kinds of intermediate structures are obtained with different steels.

Core.—The difference is similar to that obtained in the gradation zone. Figs. 7 to 10 show normal and abnormal steel before and after carburizing. Before carburizing the structure of the two steels is very similar, but after carburizing the grain size in the normal steel has grown, as might be expected after a prolonged heating around the Ac_3 point, whereas the abnormal steel shows an actual decrease in grain size. The pearlite in the normal steel forms comparatively large shorp-cornered areas, whereas the pearlite areas in the abnormal steel are rounded, much smaller and not so well defined in outline.

A difference in structure of the same kind would of course have been produced by an anneal at the same heat, and this accounts for the difference in structure that is sometimes observed in low-carbon steels after having been submitted to a normalizing anneal around 1700 degrees Fahr. Although somewhat beside the subject under discussion, the writer wants to call attention to the importance of these different properties in steel, when machine parts are subjected to tough anneal and similar heat-treating operations, and the similarity in the problem of securing a steel with good carburizing qualities and steels that will respond readily to other kinds of heat treatment.

This difference in grain size disappears with the employment of higher temperatures, as will be shown later. This fact accounts for the similarity in structure of normal and abnormal steel before carburizing, as, for the different operations in the steel mill, considerably higher temperatures are employed. The only case when it is possible to determine in advance the carburizing qualities is when the steel is banded and filled with ghost-lines. A steel of this kind is likely to show abnormal carburizing qualities, but even this is by no means a certainty.

Steel With Intermediate Properties

The structures described above are to be regarded as the extreme limits that can be expected in commercial steels. Both of these types are comparatively scarce, and the great majority show structures between these two limits approaching one or the other. It is indeed possible to obtain a complete sequence of structures that gradually, with small changes, cover the entire field between normal and abnormal structures, and the experience has been that with this change in structure there is simultaneously a change in the way the steel responds to the hardening operation. This change in structure is perceptible both in the case, the gradation zone and the core, but is most

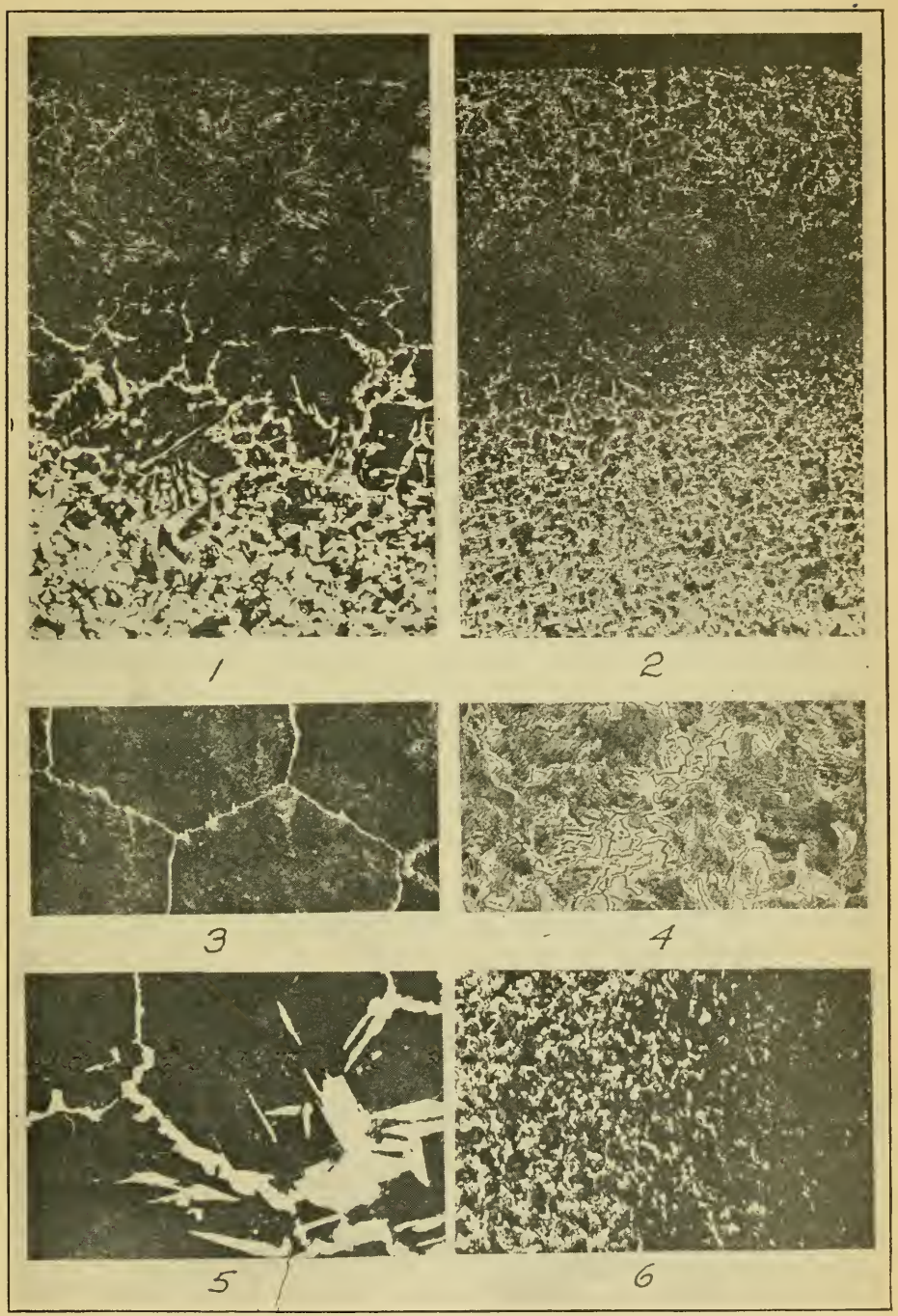


Fig. 1—Case of normal steel. Will give a martensitic case in hardening. X 50. Fig. 2—Case of abnormal steel. Will give soft troostitic spots in hardening. X 50. Fig. 3—Hypereutectoid zone of normal steel. X 200. Fig. 4—Hypereutectoid zone of abnormal steel. X 200. Fig. 5—Graduation zone of normal steel. X 100. Fig. 6—Graduation zone of abnormal steel. X 100.

clearly visible in the hyper-eutectoid zone and only photomicrographs from this zone are, therefore, given in description of these steels. The change in the gradation zone is toward pearlite areas with rounded outlines instead of angular, and with increasing abnormalty also a diminishing of the grain size.

The change in the hyper-eutectoid zone starts with the cementite changing from straight lines to lines with knotty appearance as in Figs. 11, 12 and in somewhat more advanced cases, also with an irregular and smaller grain size as in Figs. 13 and 14. In perfectly normal steel the cementite is often found as perfectly straight needles through the crystals but in slightly abnormal steel the needles are knotty and interrupted with an appearance such as shown in Fig. 15. This tendency of the cementite to be precipitated as needles is different in different steels, but just exactly what conditions cause this phenomenon, the writer is unable to state. That a high temperature will cause this structure is above doubt (Figs. 35 and 36) but the writer believes that the deciding factor at usual carburizing temperatures is some inherent property in the steel itself rather than the rate of cooling, an opinion that seems to be prevailing in the literature.

The above types constitute the limit where a successful hardening can be accomplished. The next steps are shown in Figs. 16 and 17, where the grain size is still smaller and the cementite is no longer present as continuous lines but as more or less curly and knotty fragments.. A starting divorce of pearlite is often noticed in this type. Still more pronounced abnormal structures are shown in Figs. 18 and 19, both of which can be regarded as absolutely hopeless in regard to hardening and which never should be used for case-hardening purposes.

A different type of structures that does not fit in well in the above series is a type where the grain size is fairly large but the cementite is surrounded by ferrite from a partial disintegration of the pearlite as shown in Fig. 20. This type of steel gives very poor results in hardening with a tendency to form soft spots, which contrary to the usual types of abnormal steel with fine grain size after hardening, results in a coarse and "fiery" fracture. Another type contains abnormal and normal parts intimately mixed in the same section throughout the case and the core as in Fig. 21. This structure is regarded with great suspicion as an indication that other parts of the steel might be of unmixed poor quality.

Variation in Depth of Case and Maximum Carbon Content Caused by the Steel

Several authors when writing of carburizing give detailed and exact figures as to the depth of case and the maximum carbon content that will be obtained with different carburizing reagents and different temperatures. How they have been able to obtain these figures down to 0.001 inch is a mystery to the writer, as it is hardly possible to obtain the depth of case with a microscope closer than within 0.005 inch, and even to obtain figures of this accuracy personal judgment is necessary. The depth of case is seldom exactly the same all around a piece, and two pieces carburized close together in the same pot often show a difference of as much as 0.005 inch, which of course is of no commercial importance, but nevertheless true in spite of all the claims to the contrary made by agents for different carburizing compounds.

In regard to the influence of the steel on the depth of case, the writer could give figures from carefully recorded tests on a laboratory scale, but

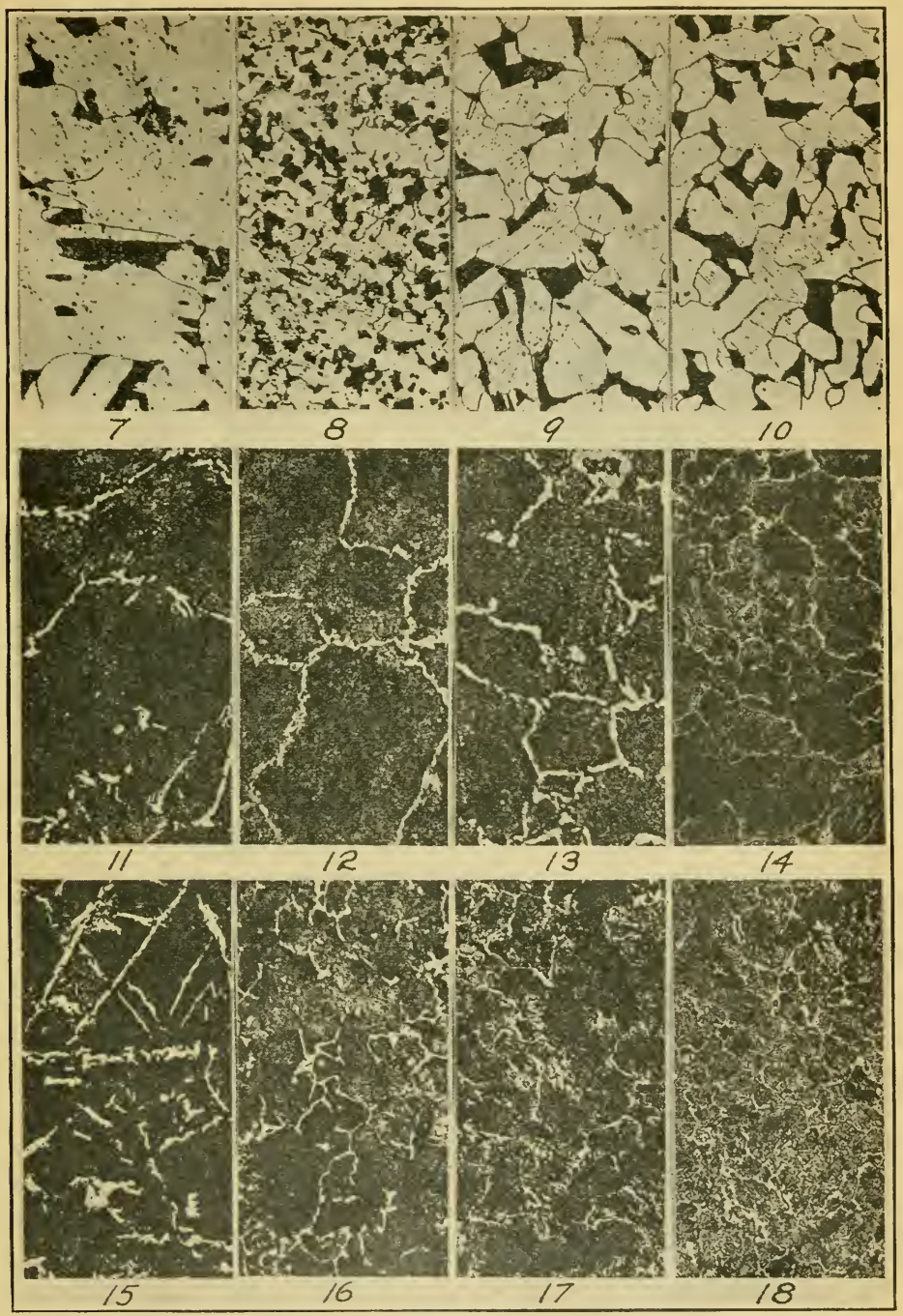


Fig. 7—Core of normal steel. X 100. Fig. 8—Core of abnormal steel. X 100. Fig. 9—Same steel as in Fig. 7 before carburizing. X 100. Fig. 10—Same steel as Fig. 8 before carburizing. X 100. Figs. 11, 12, 13, 14, 15 and 16 show steel having hypereutectoid zones of slightly abnormal type. X 200. Fig. 17—Hypereutectoid zone of abnormal type. X 200. Fig. 18—Hypereutectoid zone of abnormal type. X 200.

rather than giving these, he prefers to relate the experience in this respect that has been obtained under operating conditions.

Cones are usually packed inside the cups of the same bearing, but it is not unusual to receive a report from the carburizing department that this packing schedule has to be changed for certain lots, due to a slower penetration than normal in either the cups or cones. On investigation it is always found that the parts that were slow in carburizing were made of abnormal steel. Laboratory experiments verify this experience, and although it is hard to give exact figures, a maximum difference in depth of case of 15 to 20 per cent can be considered as a fairly good value. This statement is valid only for temperatures around or below 1675 to 1700 degrees Fahr., whereas at higher temperatures an abnormal steel will appear to carburize as fast as normal steel, but the writer is not ready to make any positive statements on this point, as his experience is based only on laboratory tests with a few specimens, and on a limited scale.

This feature in an abnormal steel giving a shallow case is combined with a tendency toward a higher maximum carbon content at the surface. On account of the pearlite divorce, it is usually impossible to determine microscopically with any accuracy the carbon content in the case of a steel of this kind, and an inexperienced observer is even likely to judge a very high-carbon case to be hypo-eutectoid or strongly decarburized. A normal steel gives no difficulty in this respect. It is thus necessary to resort to a chemical analysis, which of course, gives the only absolutely reliable figures. In one experiment, two test rings of identical shape, made of different steels, were packed close together in the same carburizing pot. The first cut of 0.010 inch showed a carbon content of 1.20 per cent in the abnormal, as compared with 1.07 per cent in the normal steel. This is a very undesirable feature, and makes, as will be shown later, the hardening of the abnormal steel still more precarious.

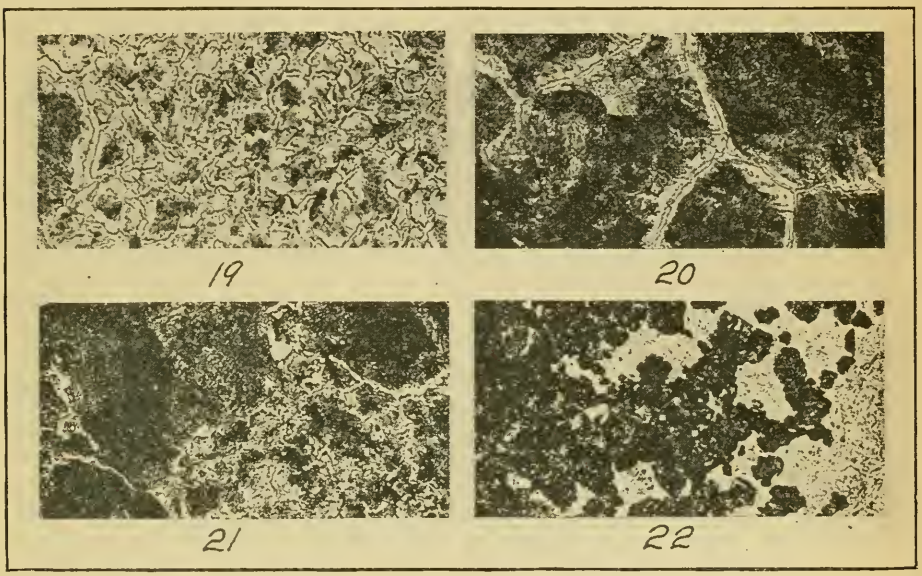
It is also noticed that the hyper-eutectoid zone of a strongly abnormal steel shows a more pronounced demarcation at the eutectoid zone than does a normal steel. This is caused by a stronger enfoliation during the cooling, as it is well known that at the carburizing temperature the carbon content decreases uniformly from a maximum at the surface to a minimum represented by the carbon content of the core. This enfoliation is presumably caused by the strong repelling action on the carbides from the impurities present in abnormal steel. A comparison is the formation of ghost-lines in steel, and this feature is also, by the way, a direct parallel to the fact that a nickel steel, which contains the nickel in solid solution in the ferrite, shows more enfoliation than a chromium steel where the alloying element is contained mainly as double carbides.

Hardening of Normal and Abnormal Steel

Briefly stated, normal steel will respond to heat treatment readily, and in the hardening operation will form martensite and become uniformly hard, while the abnormal steel will not respond readily, and in its worst varieties will not under any circumstances harden without soft spots. These soft spots are of irregular shape, size, and distribution. To a file they are more or less soft, and scleroscope readings run from 45 to 60, as against 75 to 90 for normal steel. Microscopical examination shows their structure to be more or less, and sometimes entirely, troostitic as shown in Fig. 22. On rehardening a carburized piece of this kind it is often found that the previously soft areas become hard, but also that, almost invariably, new soft spots de-

velop. In less extreme cases it also happens that the hardening is so far successful that the work appears hard to the file, but shows a soft surface after removing by grinding off a few thousands of an inch. That this phenomenon is not due to careless grinding, but to a hardness only surface deep, has been carefully checked.

Although somewhat more unusual, cases are found where the entire surface is soft. In one case, for instance, the carbon content was found by analysis to be 1.10 per cent in the outside layers, and in spite of extreme



Figs. 19 and 20 show steels having a hypereutectoid zone of abnormal type. X 200. Fig. 21—Hypereutectoid zone with mixed normal and abnormal structure. X 200. Fig. 22—Edge of soft spot showing troostite in hardened abnormal steel. X 200.

care in hardening under the writer's personal supervision the pieces were so soft that there was no difficulty in removing the entire case by filing. Failures in hardening of similar kinds of steels have from time to time been referred to the writer for investigation, by different manufacturers of case-hardened parts, and the failures have almost invariably been found to be due to more or less abnormal steel.

It is very often noticed that the surface of an abnormal steel after carburizing is spotted and unevenly colored, whereas the surface of a normal steel with the compound used gives a clean, uniformly grey surface. A similar difference is sometimes observed also after hardening.

The primary considerations in hardening of carburized work, as in all other hardening, are the hardening temperature and the accomplishment of a proper quench. The problem of hardening carburized normal steel is similar to that of hardening a well made tool steel. Several other precautions both as to temperature and quench must, however, be taken with abnormal steel, as the temperature must be raised and the quench made much more drastic than is necessary for normal steel. These points will be dealt with separately.

Influence of Hardening Temperature

A normal steel will, in the absence of excess cementite, give a properly refined case if hardened from 1420 to 1430 degrees Fahr. This applies to

work of small dimensions, but even for large sized work the temperature should never need to exceed 1450 to 1460 degrees Fahr., and if a higher hardening temperature is employed a coarse overheated fracture will be obtained. An abnormal steel behaves quite differently in this respect, and gives a fine-grained fracture even if the hardening heat be raised considerably above normal. It has even been found that in the case of the most abnormal steels, specimens quenched directly from the carburizing pots show fractures of the case resembling those of well-hardened, high-carbon chromium steel, whereas of course a normal steel quenched under the same conditions shows a very coarsely grained fracture.

Independent of the hardening temperature, very abnormal steel will harden with soft spots, but it has been found that with many of the intermediate types of steel an increase in temperature is beneficial. By using a hardening temperature up to 1525 degrees Fahr. a large amount of work can be salvaged, although this process is far from 100 per cent efficient. The proper hardening heat is determined by gradually raising the temperature, testing the hardness by file test, and breaking samples for examination of the fracture. This increase in temperature must be carefully watched, as different steels respond in different ways, and the cases where a fine-grained fracture is entirely independent of the hardening temperature are restricted to steels distinctly abnormal. Great care must also be taken, by periodical breaking of samples, that no work of normal steel is given this hardening at the higher temperature, which would result in a coarse-grained, entirely unsatisfactory fracture of inferior quality. In this respect the previously mentioned spotty appearance of some lots of abnormal steel is also a good indication. The soft spots are sometimes accompanied by a somewhat fiery coarse-grained fracture that cannot be refined by the employment of any hardening method. The fracture is somewhat similar to that obtained when the case, for one cause or another, is a little high in excess carbon, but is of a distinctly different nature and is undoubtedly due to some abnormality in the steel. The exact nature of this has, however, not yet been established, primarily because this fracture is comparatively scarce. The fracture has been observed in several types of abnormal steels, but is especially obtained when the steel in the carburized condition shows signs of pearlite divorce around isolated lines of cementite combined with a fairly large grain size.

In order to avoid any doubt as to the accuracy of the temperature given, it can be mentioned that they are all checked by recording instruments of potentiometer type in connection with platinum-rhodium couples, checked periodically against standard couples. The hardening furnaces are of the rotary hearth type with a central combustion chamber for oil or gas, and the temperature is controlled within ± 5 degrees Fahr. by automatic regulators of the company's own design.

It has been suggested that the reason for the failure in hardening abnormal steel would be that the cementite in the hyper-eutectoid zone once precipitated, could not again be readily brought into solution. This would not, however, explain why samples quenched directly from the carburizing pots show soft spots, and it has, moreover, through laboratory experiments with gradually increased hardening temperatures, been proved that the excess cementite is dissolved without difficulty. That the troostite formation is due to some other factor detrimental to the formation of martensite is above doubt and will be discussed later. Attention is, however, directed to the parallel of unstable pearlite in the carburized and unstable martensite

in the hardened steel, notwithstanding that in the hardening the troostite formation probably occurs directly from the austenite and does not pass the martensitic stage.

Influence of Proper Quench

In the hardening of common tool steel a faster quench than immersion in brine or flowing water is seldom necessary, and this is equally true of carburized work made from normal steel. The extreme types of abnormal steel cannot, however, be hardened under any conditions, and even intermediate types need a faster quench than that obtained by immersion of the work. This fact and the possibilities of much greater production have led to the adoption of a very powerful spray quench in specially designed hardening machines, working with water under a minimum pressure of 40 to 50 pounds per square inch and a maximum temperature of about 65 degrees Fahr. The use of this machine, facilitates the use of different quenching mixtures, resulting in a minimum warpage and uniform change in size. By this method all except the very worst types of steel can be satisfactorily hardened, especially if, in doubtful cases and for large work, the hardening temperature is raised as previously mentioned.

Influence of Maximum Carbon Content on the Case

It is, desirable to keep the carbon content as close to the eutectoid composition as possible, but this is especially for heavy cases, very difficult. When excess carbon is present in a normal steel the result will be freckled edge, but the hardness is not materially affected, even if the strength is lowered. The writer's experience with abnormal steels is that the difficulty in hardening, as regards soft spots, is greatly increased with the presence of excess carbon. This experience agrees well with the results by Portevin and Garvin[1] on the influence of the rate of cooling on hardening of carbon steels. Their investigation proved that a faster rate of cooling is necessary for the proper hardening of hyper and hypo-eutectoid steel than for eutectoid steel. This condition makes it still more difficult to harden an abnormal steel, which, as already mentioned, has a tendency to build up a higher carbon case than a normal steel, and it can be safely stated that even with steels of very abnormal types, the presence of excess carbon (1.05 per cent or more) is a necessary condition for the complete development of a soft surface in the hardening. As this condition is likely to be present in large sized work with heavy cases, most of the difficulty in hardening is experienced with work of this kind. A contributing factor to this is that the speed of quenching is slower for the larger than it is for the smaller work.

Based on this principle of keeping the carbon content as close to the eutectoid as possible, a method of salvage has been worked out that has been used with at least fair success in several instances where the work failed in hardening. The method consists simply in heating the work in a non-carburizing medium, such as saw-dust or coke breeze, for a sufficient time to allow for the diffusion of the excess carbon toward the core. In the subsequent hardening operation much better results are obtained, and although the method is far from fool-proof, several lots of especially large work ready for the scrap pile have been saved in this way. The application of the theories of Portevin and Garvin to the explanation of the failure in hardening will be dealt with later.

1. Journal of the Iron & Steel Institute, 1919, No. 1, pp. 469-560.

Part II

Influence of Carburizing Temperature and Rate of Cooling On the Carburized Structure of Normal and Abnormal Steel

The structures described in Part I were obtained with a carburizing temperature of 1675 to 1700 degrees Fahr., followed by cooling in the pot. In order to develop a carburizing test that could be made on a laboratory scale and in the shortest time possible, experiments were run with higher carburizing temperatures and other changes that seemed likely to produce a rapid result. For the tests, specimens from two bars, one of normal and one of

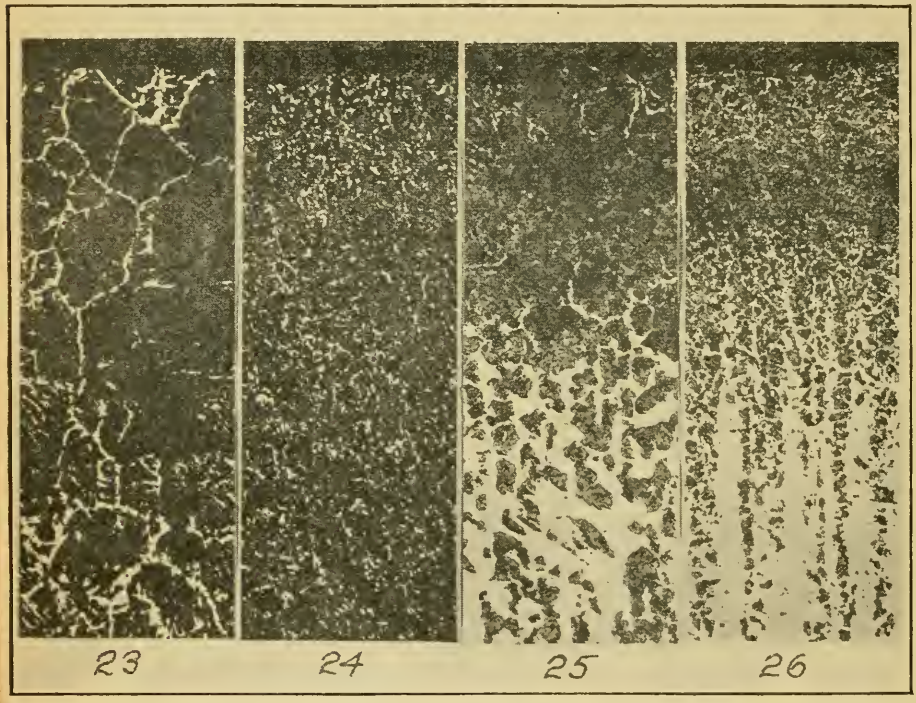


Fig. 23—Case of normal steel obtained with slow carburizing compound. X 50. Fig. 24—Case of abnormal steel obtained with slow carburizing compound. X 50. Fig. 25—Case of normal steel carburized for 8 hours at 1600 degrees Fahr. X 50. Fig. 26—Case of abnormal steel carburized for 8 hours at 1600 degrees Fahr. X 50.

abnormal steel, were packed with different compounds in small containers of 1½-inch x 6-inch steel pipes. The containers were heated in an electric furnace at 1600, 1700, 1800, 1900 and 2000 degrees Fahr. for varying lengths of time. One set of containers were also heated in a high-speed steel furnace at about 2250 degrees Fahr. The influence of the rate of cooling was studied by cooling at four different rates, as will be shown shortly.

Influence of Carburizing Compound and Time at Maximum Temperature

The variation in structure produced by different compounds is very slight. A fast carburizer will, however, give a test in a shorter time and the carbon content in the case will be higher, which, as already mentioned, is favorable to the development of the differences in structure, and compounds giving an eutectoid case are on this account not well suited for tests of this kind. Very

slow carburizers, for instance coke with a weak energizer such as glue, will give a hypo-eutectoid case, and the difference in structures obtained is similar to that in the gradation zone, but is much more pronounced and sometimes affords a very sensitive test as shown in Figs. 23 and 24. The influence of time is comparatively small, although a long heating accentuates the difference, due to the fact that a deep case always has a tendency for a higher carbon content at the surface. With a temperature of 1700 degrees Fahr. and an energetic compound a very distinct difference is obtained in two to three hours, but for actual tests, at least three to four hours should be allowed.

Influence of Carburizing Temperature

There are, as already mentioned, two distinct and different features characteristic of the structure in a carburized piece, namely the hyper-eutectoid zone, the gradation zone and the core. In an abnormal steel the structure in both these respects is changed with an increased temperature, but the change does not occur at the same temperatures. With the steel used for these tests the change in structure of the gradation zone and the core occurred at 1750 to 1800 degrees Fahr. whereas the change in the hyper-eutectoid zone occurred at about 1900 degrees Fahr. The structure in the normal steel at these temperatures remained practically unchanged (Figs. 25 to 34.)

The gradation zone and the core in an abnormal steel are, with low carburizing temperatures, fine-grained, with rounded pearlite areas. With an increased carburizing temperature this structure gradually disappears and a structure identical with that of a normal steel is obtained. With the two steels tested the dividing temperature range was 1750 to 1800 degrees Fahr. but this temperature is likely to vary with different steels, being higher for the very abnormal types. The structure of the hyper-eutectoid zone of an abnormal steel at a low carburizing heat is fine grained, with knotty or curly cementite and more or less disintegrated pearlite. In the tests made this structure gradually disappeared with an increase in the carburizing temperature, but persisted to a considerably higher point than the structure in the gradation zone and the core. The dividing temperature range was about 1900 degrees Fahr. and somewhat dependent on the carburizer employed, with a slightly higher temperature for a very energetic compound. Above this temperature both the normal and the abnormal steel showed a tendency to form a needle-like structure, although a slight difference was noticed up to about 2000 degrees Fahr. At still higher temperatures the structure was identical in both steels, consisting of solid pearlite with the cementite as very pronounced needles (Figs. 35 and 36.)

Influence of Rate of Cooling

The influence of the rate of cooling is considerably less than might be expected from previous investigations, and is quite overshadowed by the influence of the quality of the steel. The different rates of cooling and how they were obtained are shown in Table I. The table refers to the tests run at 1800 degrees Fahr. but the rates obtained at other temperatures were similar.

At the slowest rate of cooling there is a very pronounced enfoliation of the case and segregation both in the case and the core, as would be expected, but otherwise the structure is very similar to that obtained in the regular practice, and with the pipes cooled in kieselguehr or in the air, photomicrographs of which are shown in Figs. 37 and 38.

Specimens cooled freely in the air showed, on the other hand, a very

pronounced difference with the enfoliation and segregation almost entirely suppressed. At the edge, the excess cementite has not had time to segregate, but is precipitated uniformly through the pearlite, and the gradation zone and the core, especially at the higher temperatures, have a tendency to show the typical triangular structure of overheated steel as shown in photomicrographs Figs 39 and 40. At a slightly slower rate of cooling this structure is modified by coagulation phenomena, as previously shown.

Recommendations for Short Time Carburizing Tests

In order to obtain the greatest difference between different steels it is desirable that the structure be well developed both in the hyper-eutectoid and

Table I

Method and Time Required in Cooling Specimens After Carburizing

Method of Cooling	Temperatures and Time Required to Cool Specimens: 1800 to 1700 degrees	1700 to 1800 degrees	1800 to 1500 degrees	1500 to 1400 degrees	1400 to 1300 degrees
1. Pipes cooled in furnace.....	45 minutes	1 hour	1 hour 30 minutes	3 hours	6 hours
2. Pipes cooled in kieselguhr.....	5½ minutes	2½ minutes	2 minutes	2 minutes	2 minutes
3. Pipes cooled in air.....	3 minutes	1½ minutes	1½ minutes	1½ minutes	1½ minutes
4. Specimens cooled in air.....	———	——1800 to 1300 degrees in about 2 minutes———			

the gradation zones, although these requirements are to a certain degree contradictory. The most distinct difference in the hyper-eutectoid zone is obtained at about 1800 degrees Fahr. but at this temperature the transition zone will be coarse-grained, independently of the quality of the steel. In order to develop the typical fine-grained structure in this part and in the core of an abnormal steel it is thus necessary to use a lower temperature. The best results seem to be obtained at 1675 to 1700 degrees Fahr. and by using an energetic compound and small containers the tests can be made in a total time of three to four hours.

One method by which very fast and satisfactory results are obtained is by carburizing under pressure. The easiest way to effect this is by using closed containers, preferably made of some heat-resisting alloy, with tight-fitting covers and a carburizing meal that gives off plenty of gases during the time of heating. In carburizing as commercially conducted these gases are allowed to escape, but can be utilized to build up the desired pressure. In this way it is possible to obtain a distinctly hyper-eutectoid zone in a short time at a comparatively low temperature. Very sensitive results are also obtained by using a slow carburizing compound at a temperature of about 1700 degrees Fahr. In this way a maximum carbon content of .60 to .70 per cent is obtained, and the difference in structure is often very pronounced. For an all-round test the method with a fast carburizer, capable of producing a hyper-eutectoid case, is, however, to be preferred.

Part III

Explanation of Structures and Phenomena Encountered in Case-Hardening of Normal and Abnormal Steel

With the fact clearly established that the different structures and properties of carburized steel were due to some inherent property in the steel itself, present in the ingot and unchanged by later operations in the course of manufacture, it became necessary to establish the causes, and if possible duplicate these phenomena under laboratory conditions. The writer believes that both of these problems have been successfully accomplished and the conclusion arrived at is, that they are caused by the presence in the steel of

minute ultra-microscopical solid particles of non-metallic impurities, presumably oxides, due to improper deoxidation of steel when made. For details in regard to proof for this contention, the earlier papers (See Page 1 of original manuscript) and following discussions are referred to. The following summary of the different points in favor of this theory will be sufficient:

1. *Behavior and structure of ghostlines in carburized work.* (*Fig.* 41)

2. *Influence of artificially produced inclusions and of fragments of mill scale in carburized work.* (Figs. 42 *and* 43)

3. *Structures produced in welding, followed by carburizing.* (*Fig.* 44)

4. *Carburizing qualities of burnt steel and steel exposed to oxygen in the molten condition.* (*Figs.* 45 *and* 46)

5. *Carburizing qualities of steel as connected with furnace practice and different stages of electric furnace heats.* (*Figs.* 47 *to* 50)

6. *Influence of different deoxidizing reagents.*[2] (*Figs.* 51 *and* 52)

It is freely admitted that the evidence is somewhat circumstantial and that it has been subjected to some rather severe criticism, but it is also true that in addition to several of the leading American metallurgists, who have accepted the proof as conclusive, the well-known French scientist, Professor Portevin, who is especially entitled to speak with authority on this subject, in a contribution to the discussion of the paper presented at the Iron & Steel Institute, endorses the writer's theories and mentions that he has independently been led to similar conclusions.

Just how this influence from the oxides in the steel is exerted in order to produce the properties described as normal and abnormal, has been a matter of much speculation. That the oxides are evenly distributed through the steel is beyond doubt, but whether in solid solution, in colloidal solid solution, or suspended as minute particles in the steel, is very difficult to decide. There is, for one thing, no difference in the heating and cooling curves of the different steels, and the fact that the rate of diffusion of the impurities is very slow, as shown by the perseverance of unmixed normal and abnormal portions of steel in the same specimen, even after prolonged heating, gives certain support to one of the two latter theories. The fact, on the other hand, that in steel surrounding inclusions of mill scale, an actual solution and diffusion of the oxides take place, affords certain support to the theory that the oxides are actually in solid solution in the steel and that an equalization does not take place in steel with mixed structures should, according to this view be due to the solution pressure being so much lower than that of the concentrated bodies of oxides in the latter case. The writer personally is most inclined toward a theory of colloidal solid solution, but for a satisfactory theoretical explanation of the phenomena encountered in carburizing and hardening these considerations can be laid aside although they are of great theoretical interest.

If a theoretical explanation of this nature is accepted, it becomes quite evident that the oxygen content determined, for instance, by the Ledebur method, will not in any way be an indication of the properties of the steel. An analysis of the oxygen content will mainly give the oxygen content of the occluded gases, which have no influence on the structure and will probably not include the

2. Experiment by Dr. Boylston, Carnegie Scholarships Memoirs, 1916, Vol. VII, Experiment II.

oxygen content of the oxides, as a reduction of the oxide particles will be very difficult to obtain. If the oxide particles consist of SiO_2 or Al_2O_3, such a reduction will manifestedly not take place, and in at least a few experimental cases, evidence has been obtained that Al_2O_3 actually was the active body in causing abnormal properties.

Explanation of Structures Obtained in Carburizing Before Hardening

Recalling the differences between normal and abnormal steel, the following features should be explained:

	Normal Steel	Abnormal Steel
Depth of case and maximum carbon content.	Deeper, with less maximum carbon content than abnormal steel.	Thinner, with higher maximum carbon content than normal steel.
Core	Large grain size. Angular outline of pearlitic areas. (Fig. 7.)	Small grain size. Rounded outline of pearlitic areas. (Fig. 8.)
Gradation zone	Same. (Fig. 5.)	Same. (Fig. 6.)
Hypereutectoid zone...	Large grain size. Cementite at grain boundaries in network. Large solid areas of pearlite. (Fig. 3.)	Small grain size. Cementite as curly fragments surrounded in extreme cases by ferrite formed by the more or less complete disintegration of the pearlite. (Fig. 4.)

The combination of a shallow case and a higher carbon content in abnormal steel can be explained in the following way. In the carburizing pot the carboniferous gases, chiefly CO, will at the carburizing temperature penetrate into the steel and deposit part of their carbon content. Just how deep this penetration of the gases is, is somewhat doubtful, but it is well known that the higher the pressure of the gases, the deeper will be the case and the deeper will presumably be the penetration of the gases into the steel, or at least the deeper will the penetration of active gases be, before they have been deprived of their surplus carbon by the surrounding iron. At the low pressure that is used in commercial carburizing practice, it is reasonable to assume that most of the carbon is deposited close to the surface and that this amount of carbon is practically independent of whether the steel is normal or abnormal. The transportation of carbon toward the core in a piece being carburized can, however, be visualized as taking place not only by means of the carboniferous gases, but also by the migration of the carbon, and on this diffusion toward the core of the carbon, impurities are likely to have a strongly repelling influence. This will, if as presumed, approximately an equal amount of carbon is deposited close to the surface of the steel, result in a thin case with higher carbon content for the abnormal steel.

The variation in grain size that is noticeable both in the case and the core is a question of extreme interest, as it opens up the question of control of crystallization and grain size in iron obtained not only in carburizing but also in all other kinds of heat treatment operations. The writer has observed a large variation in grain size not only in plain carbon steels, to which this article mainly refers, but also in a large number of different steels containing such alloying elements in varying proportions, as chromium, nickel and vanadium. The analysis of the steel has undoubtedly some influence, but is by no means the predominant one and the writer is inclined to believe that the grain size in the steel in general after heating at temperatures around and below the Ac_3 point, are largely governed by the presence in the steel of non-metallic impurities. Their effect is exaggerated by a carburizing operation, but are readily obtained also after prolonged heating at the proper temperature without a carburizing compound.

The different properties of normal and abnormal steel were, as already men-

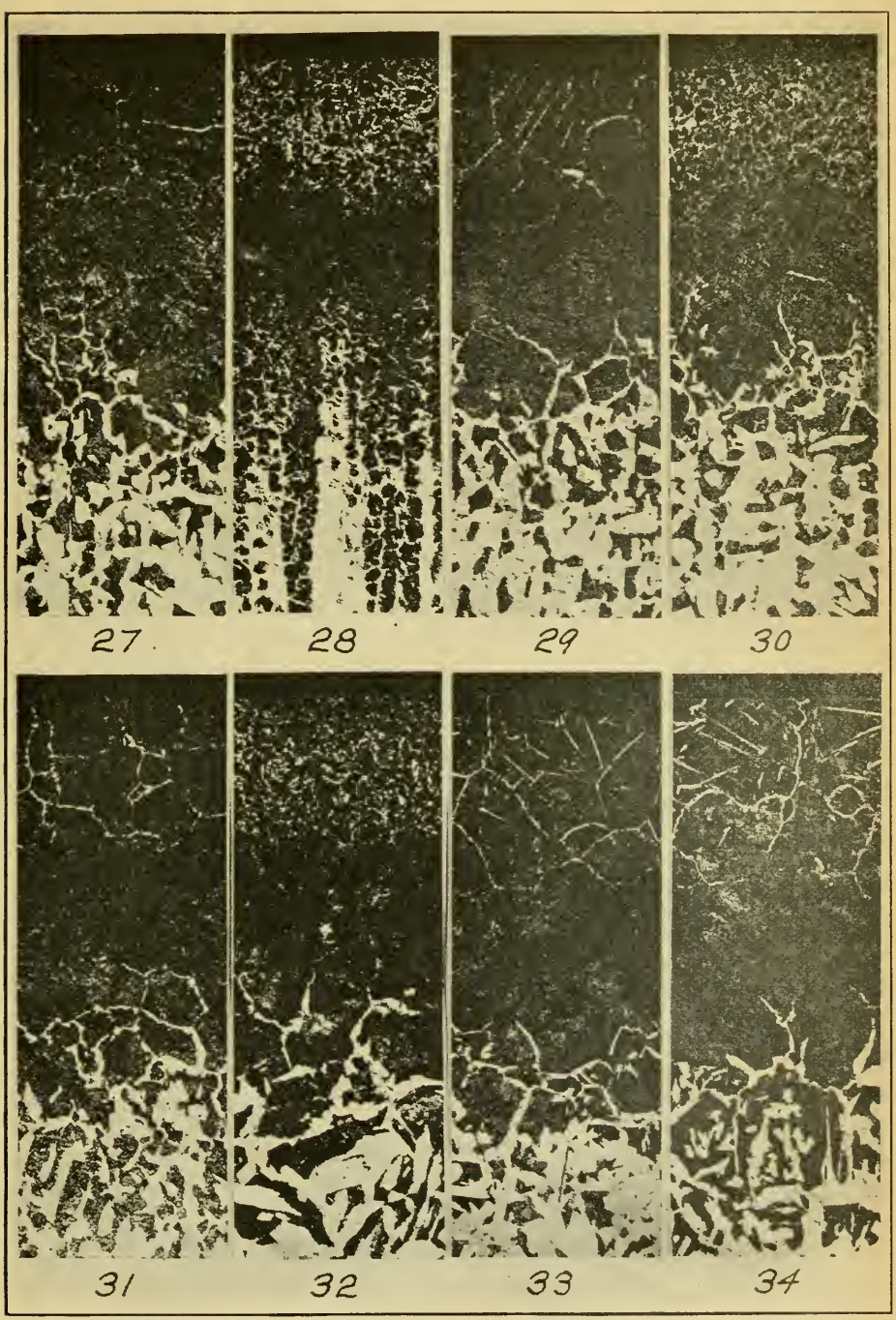


Fig. 27—Case of normal steel obtained in 8 hours at 1700 degrees Fahr. X 50. Fig. 28—Case of abnormal steel obtained in 8 hours at 1700 degrees Fahr. X 50. Fig. 29—Case of normal steel obtained in 8 hours at 1800 degrees Fahr. X 50. Fig. 30—Case of abnormal steel obtained in 8 hours at 1800 degrees Fahr. X 50. Fig. 31—Case of normal steel obtained in 2 hours at 1900 degrees Fahr. X 50. Fig. 32—Case of abnormal steel obtained in 2 hours at 1900 degrees Fahr. X 50. Fig. 33—Case of normal steel obtained in 2 hours at 2000 degrees Fahr. X 50. Fig. 34 Case of abnormal steel obtained in 2 hours at 2000 degrees Fahr. X 50.

tioned, in an early stage of this investigation, traced back to the ingot and the different characteristics in regard to grain size have presumably originated during the solidification of the steel in the ingot. Professor E. D. Campbell of the University of Michigan who was consulted on this subject wrote in reply to a question by the writer as follows:

"In regard to the diminution in grain size, where impurities are present, I think it is not improbable that this is due to the increase in the number of centers of crystallization, as it is well known in ordinary solutions that to obtain large crystals the number of centers of crystallization should be reduced to a minimum. As you probably know, if crystallization in a solution can be started at one point only a single crystal will often grow to a remarkably large size, whereas agitation of the solution or the addition of dust or other small particles of solid materials which serve as centers of crystallization, will bring about the formation of a very large number of small crystals or grains. In normal steel the grain size will depend upon the composition, initial temperature, and the rate of cooling, and it is at least thinkable that a local increase in the concentration of impurities might, by increasing the number of crystallizations, produce a very marked change in grain size."

According to this theory, the starting points for crystallization in a "clean" and well-deoxidized steel are much fewer than in the abnormal steel, where a large number of oxide particles serve as starting points for the crystals. In the normal steel comparatively few well-developed crystals are obtained, while in an abnormal steel the large number of crystals interfere with the growth and development of each other. This explains the cause of both the larger grain size with the angular or triangular outlines of the pearlite in a normal steel (Fig. 5) and the smaller and more rounded areas of pearlite in an abnormal steel (Fig. 6). This point of view is supported by the experience of Dr. Giollitti[3], from whom the following quotation is taken:

"Solidification must start somewhere, and it is known that the first nuclei appear at determined points in the cooling melt. As I have already mentioned, the formation of the first germs of crystallization is one of the most important phenomena among the many occurring during solidification. The properties characteristic of the solid alloy depend to a very large degree upon the number of centers of crystallization and the cause of their formation. So strongly, in fact, does this state of affairs impress itself upon the metal, that the vestiges remain even after all the heat treatment and mechanical work to which it will be afterwards subjected."

That the way the solidification takes place is of primary importance for the future properties of the steel is thus above doubt, and by assuming that the oxides are distributed as minute particles in the steel, presumably in a colloidal solution, and that they retain their mutual positions in the steel, and later, under favorable conditions arrange the crystals in accordance with this outline, an explanation would be obtained how the influence from the solidification is carried through the different stages of conversion and heat treatment of the steel. It is, however, no material deviation from this theory if the variation in grain size is considered as being caused directly by the presence of impurities in the steel, and this point of view might seem preferable, if a more direct explanation is desired. Messrs. Jeffries and Archer[4] have in a series of articles entitled "Grain Growth and Recrystallization in Metals"

3. Giollitti, "Heat Treatment of Soft and Medium Steels," translated into English by Thum and Vernaci, pp. 13 and 14.
4. Chemical & Metallurgical Engineering, Feb. 22, March 1 and March 8, 1922.

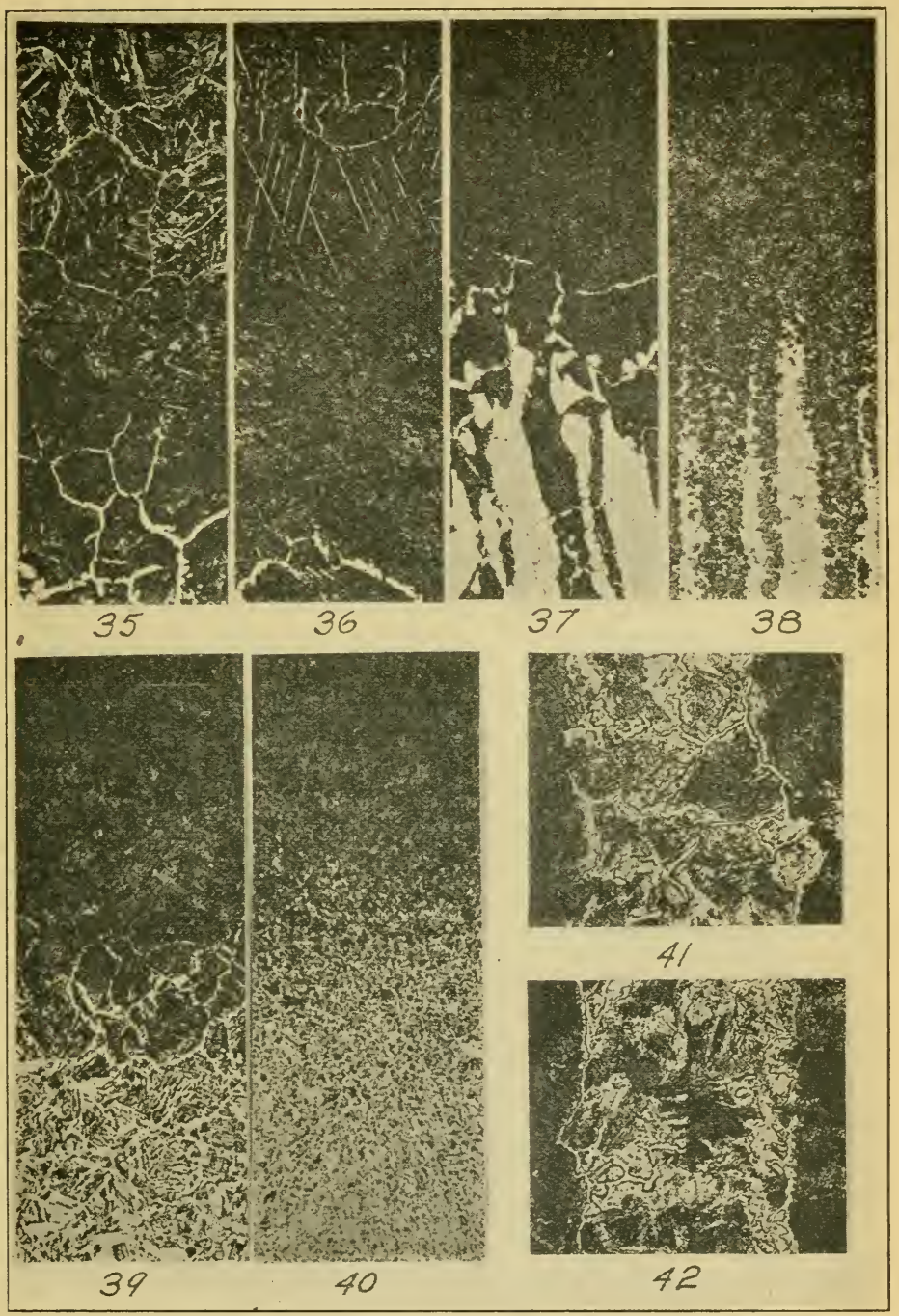


Fig. 35—Case of normal steel obtained in 2 hours at 2200 degrees Fahr. X 50. Fig. 36—Case of abnormal steel obtained in 2 hours at 2200 degrees Fahr. X 50. Fig. 37—Case of normal steel carburized at 1600 degrees Fahr. for 8 hours cooled very slowly. X 50. Fig. 38—Case of abnormal steel carburized at 1600 degrees Fahr. for 8 hours, cooled very slowly. X 50. Fig. 39—Normal steel carburized at 1600 degrees Fahr. for 8 hours, cooled in air. X 50. Fig. 40—Abnormal steel carburized at 1600 degrees Fahr. for 8 hours, cooled in air. X 50. Fig. 41—Ghost-lines in hypereutectoid zone of normal steel. X 200. Fig. 42—Artificial inclusion of manganese sulphide in the hypereutectoid zone of normal steel. X 200.

made an exhaustive study of the factors governing recrystallization and grain size in metals, and in their articles it is shown how the presence in a metal of finely divided impurities will under favorable conditions, cause a fine grain size. Their experiments were made with thoria and tungsten, but there are many indications that similar laws govern the grain size in steel, with non-metallic impurities as the obstructing material against grain growth.

Just of what kind and of what concentration these impurities must be to influence the grain size in steel is very difficult to ascertain, but there is reason to believe that any kind of finely divided impurities in solid solution will produce this effect. This has been shown by introducing various chemical compounds into drilled holes in bars of normal steel, that have afterwards been forged down, annealed and carburized and it has been found that a large number of bodies, usually considered as insoluble in steel, in reality are soluble to a slight extent at high temperatures, and that they invariably will produce abnormal structure and a fine grain size. That the impurities in the commercial steels dealt with in this paper, consist of oxides, or some chemical compound containing oxygen is, however, fairly certain, but it is evident that it is very difficult to determine the exact nature of these compounds, as this problem can only be approached in an indirect way.

In one or two instances it has, however, been possible to draw some direct conclusions on this point, and notably in the case when aluminum is used as a deoxidizer. It is customary when taking samples for analysis during the pouring of a heat of steel to put a small piece of aluminum into the test mold in order to produce test pieces without blow holes. A steel rich in gases to which an aluminum addition has been made, will invariably show abnormal properties with a fine grain size after carburizing, whereas the steel without the aluminum additions although containing blow holes will usually show a perfectly normal structure with a large grain size after carburizing. In this particular instance Al_2O_3 is undoubtedy the active element in causing the fine grain size. This experience is mentioned without intention of passing judgment on the value of aluminum as a deoxidizer, but it can be pointed out that if aluminum is used as a deoxidizer, sufficient time must be allowed for the Al_2O_3 to coagulate and be removed from the bath, at least if the steel is to be used for carburizing purposes.

In other cases, it is likely that the impurities consist of FeO in combination with SiO_2 or MnO, and there are certain reasons to believe that pure FeO is comparatively scarce, as FeO would be reduced by the carboniferous gases in the carburizing operation. If such a reaction took place a change in structure would be affected equal to the penetration of the carburizing gases, and such a change has been noticed only in a very few cases. The writer is at present trying to assemble added evidence on this point and experiments have been outlined to more accurately determine the factors that govern the grain size of steel in carburizing. It is hoped that these experiments later can be broadened so as to comprise the question in general of grain size in steel around and below the Ac_3 point.

The condition mentioned in Part II that the fine grain size in abnormal steel disappears with the employment of temperatures considerably above the Ac_3 point is explained by the fact that the natural tendency of grain growth from a high temperature overcomes the obstructing influence of the impurities against grain growth and the greater perseverance of the fine grain in the hyper-eutectoid zone as compared with the gradation zone and the core can

be explained by the presence of more impurities in this part in the form of excess cementite.

Relative to the structure of the hyper-eutectoid zone in carburized work, the divorce of pearlite in abnormal steel is well explained by the presence in the steel, of oxides in solid colloidal solution. The powerful repulsive influence of oxides on iron carbide is very clearly shown by the formation of ghost-lines in steel, as already mentioned in a previous part. In the case of an abnormal steel the excess cementite is precipitated with a gradually decreased temperature, and with cementite particles as nuclei the pressure from the oxides, presumably in solution in the ferrite, is strong enough to cause a partial disintegration of the pearlite, the degree of which is dependent on the amount of oxides present in the steel. Professor Campbell, when asked his opinion on this matter, gave the following answer:

"In normal steel above the critical point the carbides form a homogeneous, probably colloidal solution, which persists until the critical point is reached, when, as the gamma iron goes over to the alpha state, in which the carbides are but slightly soluble, the precipitated carbides assume the form of thin plates, characteristic of normal pearlite. It is well known that the addition of a comparatively small amount of electrolyte to any colloidal solution in water will bring about coagulation or flocculation of the colloid, and I think it not improbable that the disolved oxides in your abnormal steels function in a manner exactly analogous to that of electrolytes in aqueous solutions, thus bringing about the flocculation or coalescence of the carbides, either before transformation takes place or during the critical period.

This question of divorce and varying stability of pearlite in carburized work is closely related with the properties of pearlite in other kinds of steel, and the experience in this respect related in this paper does not agree very well with the results obtained by previous investigators. Howe and Levy[5] investigated the influence of rate of cooling and maximum temperature on the stability of pearlite, whereas an investigation by Honda and Saito[6] shows that the divorce of pearlite is influenced by carbon content and maximum temperature. The observations by these authors that a higher temperature gives a more stable pearlite, and that an excess carbon content facilitates a divorce, agrees in a general way with the writer's experience, but he has also found that the influence of the quality of the steel is at least of equal, if not of greater importance than these factors. The direct comparison between carburized pieces and the steels of uniform carbon content, employed in these previous investigations, is open to some criticism, due to influence of segregation and enfoliation phenomena in the carburized piece during the cooling, even if the writer's experience is that they do not materially affect the results obtained. In order to offset this objection, thin strips of normal and abnormal steel have been carburized through, and afterwards soaked at about 1600 degrees Fahr. for a sufficient length of time to equalize the carbon content, thus producing samples of eutectoid and hyper-eutectoid composition, that can be regarded as similar to the steel used for the earlier tests. These samples retain all the characteristics of the original steels, and there is as marked a difference in the stability of the pearlite in these specimens as in the hyper-eutectoid zone of carburized work.

It can be said that the data given in the above-mentioned papers agree with the results obtained with normal steel, but decidedly not when abnormal

5. Journal of the Iron and Steel Institute, 1916, No. II.
6. Journal of the Iron and Steel Institute, 1920, No. II.

steel is concerned. There is no reason to believe that the properties described as abnormal in this paper should be restricted to low-carbon steels, and experience in hardening spring steels, which will be dealt with shortly, gives an actual example of a high-carbon steel with abnormal properties. This is also a very important question in the annealing of high-carbon steels, which principally consists in a spheroidizing of the cementite in the pearlite. This operation is mainly governed by the way the pearlite responds to the annealing temperature and subsequent cooling, and that in this procedure the results are dependent not only on the temperature and the rate of cooling, but also on the quantity of impurities present, is quite evident. The impurities react in the same way as excess cementite and facilitate the spheroidizing of the pearlite, but they are also, on the other hand, detrimental to the proper hardening of the steel, as will be shown in the next paragraph.

Explanation of Phenomena Encountered in Hardening of Normal and Abnormal Steel

The main problem to be explained is the difficulty in hardening abnormal steel, and particularly the occurrence of some troostitic spots in the worst types of steel. The fine-grained fracture in hardened work can be explained by the same reasons mentioned for the fine-grain size in carburized work, namely, a residual influence from the solidification of the steel in the ingot, or if so is preferred, a direct obstructing influence against grain growth from the impurities in the steel. This also explains the fact that the fine-grained fracture of a hardened abnormal steel is, with previously mentioned limitations, independent of the hardening temperature employed.

In explaining the occurrence of troostitic spots, the previously mentioned article by Portevin and Garvin[7] on the influence of the rate of cooling on hardening of carbon steel gives important information. Other conditions being equal, it is a well-known fact that the formation of troostite in hardening is dependent on the rate of cooling, and these authors determined by carefully recorded cooling curves and microscopical examination, just what minimum speed of quench will give a martensitic hardening. The rate of cooling was recorded at the center of the hollow cylinder, and the speed was varied by using cylinders of different diameter, applying a spray quench of water to the outside. The results showed that the formation of troostite corresponds with a sudden evolution of heat about 1200 degrees Fahr. called by the authors Ar′, but that with a greater speed of quench, in, for example, smaller cylinders, this evolution is depressed and occurs gradually at about 600 degrees Fahr., called Ar″, giving as a result a martensitic structure. These results show that troostite, when obtained in hardening, is formed directly from the austenite and does not pass the martensitic stage, as is often assumed. This troostite former in hardening is of a rounded and bulky appearance, such as shown in Fig. 22, which represents the structure of a soft spot in hardened abnormal steel, and is of a distinctly different nature to the troostite obtained by drawing back a hardened martensitic steel, where the troostite follows the outline of the needle structure of the martensite.

Curves No. 1 and No. 2 in Fig. 53 represent graphically and somewhat exaggeratedly from the curves given in the original paper the quench at different speeds of samples made of the same steel, No. 1 corresponding to a troostitic and No. 2 to a martensitic quench. There is, in other words, for every steel a fixed and certain minimum speed of quench that will produce a

7. Journal of the Iron and Steel Institute, 1919, No. I.

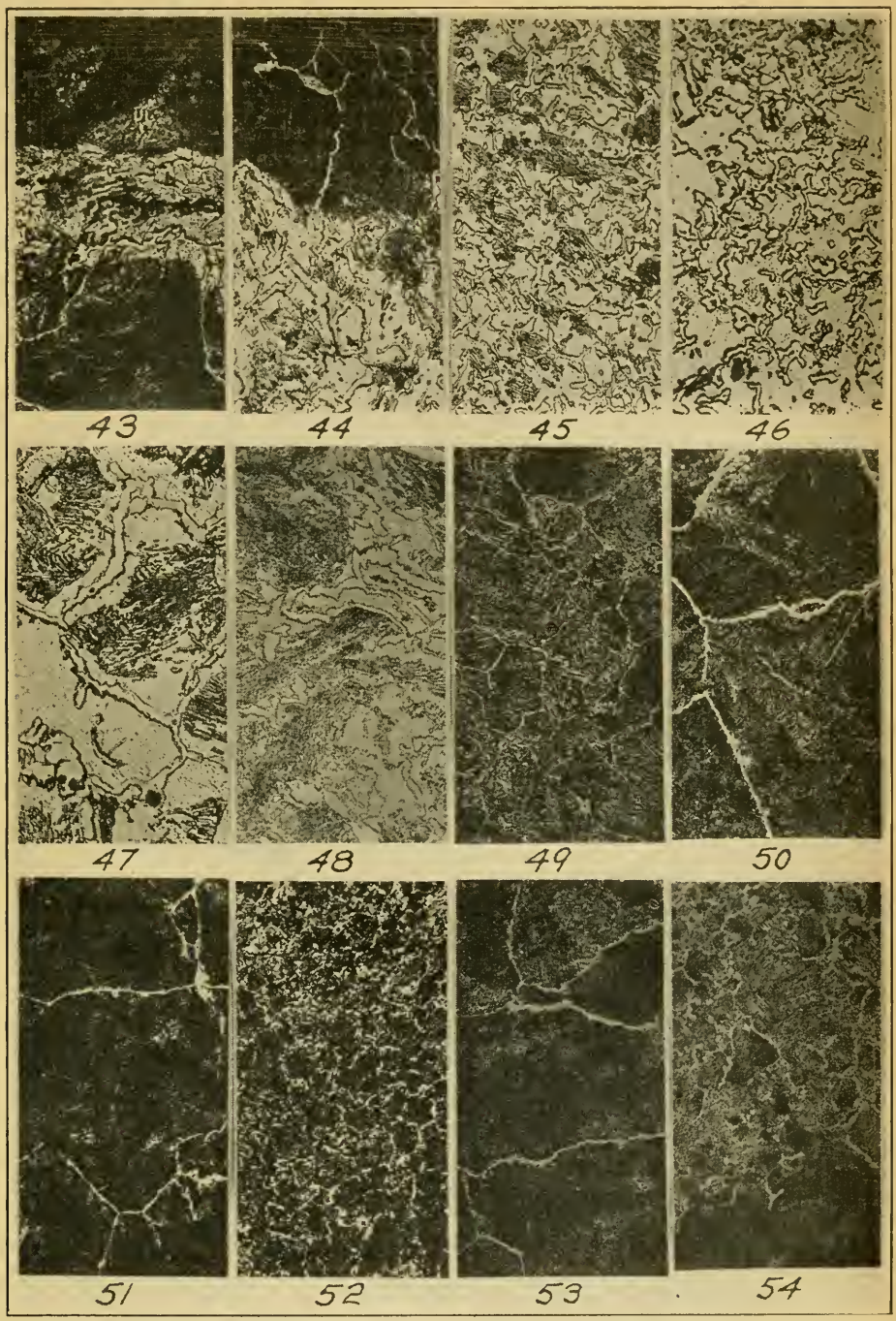


Fig. 43—Crack with mill scale close to surface—carburized. Fig. 44—Hyper. zone carb. oxy-acetylene weld. Fig. 45—Hyper. zone badly burnt steel. Fig. 46—Hyper. zone steel blown with oxygen. Fig. 47—Hyper. zone steel immediately after melting down. Fig. 48—Same steel after 1st additions. Fig. 49—Same steel immediately before tapping. Fig. 50—Same steel in finished condition. X 50. Fig. 51—Hyper. zone steel deoxidized with Fe Mn. Fig. 52—Hyper. zone steel deoxidized with carbon free Fe Ti. Fig. 53—Carb. spring steel which gave good results in H. T. Fig. 54—Carb. spring steel, erratic in H. T. All Figs. X 200.

martensitic structure, and if the quench be slower than this, more or less troostite will be obtained. Reverting to the hardening of normal and abnormal steel with the strong spray quench previously described, it can be safely assumed that with work of the same size, the same speed of quench is obtained. This means that an imaginary cooling curve of the surface of a normal steel would have the appearance of curve 3, Fig. 53, with no anomaly in the curve at 1200 degrees Fahr. (Ar′), but with a gradual heat evolution below 600 degrees Fahr. (Ar″) representing the formation of martensite, and that in an abnormal steel the cooling presumably proceeds like curve No. 4 with a heat evolution of 1200 degrees Fahr. (Ar′), corresponding with the formation of troostite, and then with approximately the same rate as curve No. 3, to 600 degrees Fahr., and from this point down, faster. In the normal steel the speed obtained by immersions is already sufficiently fast to suppress the Ar′ point, but with more or less abnormal steel this speed approaches very closely to or exceeds the critical rate. There is no doubt that if the quench could be made fast enough, it should be possible to harden even the worst types of abnormal steel satisfactorily, but this is, at least commercially, not possible, although for many intermediate types of steel that are close to the boundary line the employment of the strong spray quench brings them over on the safe side. The experiments on surface hardness in hardening by Prof. Benedicks and Dr. McCance have apparently been made with samples of normal steel, well on the safe side, and thus comparatively independent of the speed of quench.

In explaining the beneficial influence of a raised hardening heat, the experience of Portevin and Garvin was that with a higher initial temperature an indication of suppressing the Ar′ point is obtained, which fact the authors ascribe to a modification in the nature of the transformation phenomena. Apart from this, other factors that can be better controlled by an increased temperature also enter into a commercial hardening operation. When a piece of steel is quenched under commercial conditions the cooling of the surface is likely to proceed after a curve such as No. 3 Fig. 53 with a slight incline at the start of the curve, representing the cooling of the piece in the transfer from the furnace to the quenching machine and in the machine, before the quench has acquired full strength, due to steam pockets and similar reasons. It is mainly the speed with which the steel passes through the Ar′ range around 1200 degrees Fahr. that determines whether troostite formation is obtained or not, and the influence of this incline is, with normal hardening temperature, likely to reach into this critical range, and if the steel is abnormal a troostitic quench will be obtained (Curve No. 4, Fig. 53). By raising the hardening temperature this incline at the start of the cooling curve No. 5, Fig. 53 occurs at a higher temperature, and the passing of the Ar′ range is accomplished at such a high rate that formation of troostite does not occur. This applies to steel of intermediate types, whereas for steel of the most abnormal kind this suppression of the troostite formation is not possible, even with the high speed of cooling obtained in this way (Curve 6, Fig. 53).

That the different properties of the normal and abnormal steel, in regard to their hardening, are connected with the presence of oxides in the steels is beyond doubt, and there is no great difficulty in explaining how this action is exerted. The experimental results by Portevin and Garvin showed that a hyper-eutectoid steel needs a faster rate of cooling, in order to give martensite, than does a steel of eutectoid composition, the reason for this fact being that the particles of excess cementite in the hyper-eutectoid steel act as nuclei

for the formation of troostite. The action of the oxides can be explained in an identical way, and the more impurities present in the steel, the more numerous are these starting points for the troostite formation, and the faster the rate of quenching required for a proper hardening. The action, in this respect, of the oxides or any other kind of impurities can be visualized as being of very much the same nature as that of solid particles introduced into super-saturated salt solution, and a good example is afforded in the old experiment of making a super-cooled solution of Glaubers salt suddenly freeze by introducing foreign solid bodies into the liquid.

This behaviour of abnormal steel in hardening is one of the reasons why the writer is more inclined towards the theory that the solution

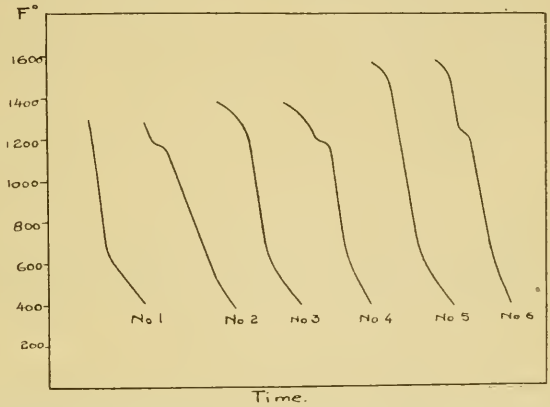


Fig. 55—Represents graphically the different quenching speeds of samples made of the same steel. For every steel there is a fixed and certain minimum speed of quench which will produce a martensitic structure. If the quench be slower than this minimum more or less troostite will be obtained.

of the oxides is of colloidal nature, with minute particles of oxide throughout the steel, just as the solution of carbide in gamma-iron probably is a colloidal solution. Such a hypothesis gives a very satisfactory explanation to properties of an abnormal steel and the different phenomena encountered in its heat treatment.

Conclusions

The results obtained in commercial carburizing are, as shown in this paper, very much dependent on the quality of the steel, and as these qualities cannot be determined by the usual chemical or physical test methods, the practical value of a carburizing test is obvious. A better product with uniform hardness, less operating trouble, and fewer rejections due to improper hardening, would be the ultimate result.

It is necessary for tests of this kind that microscopical examinations of carburized sections be made; but these do not, if properly conducted, involve a large amount of work, and after a little experience it becomes a very easy matter to determine from the carburized structure whether the steel is suitable for carburizing or not. Carburizing on a laboratory scale can be carried out in a few hours, especially if some kind of tight-fitting containers are employed in accordance with the recommendations made in Part II. It must be understood, however, that a test of one specimen from, for instance, a large heat of open-hearth steel is not a perfect safeguard against improper steel, as different

parts of a heat often show different carburizing qualities. Even one sample from each heat is, however, likely to catch the worst cases, and if several samples from each heat are tested, a reasonable security against improper steel should be obtained. Tests of this kind constitute moreover, a distinct warning to the steel mills not to send their off-heats to consumers who are known to submit the steel to tests of this kind.

For most carburizing purposes, a clean, well made, straight low-carbon steel (S.A.E. 1020) would be satisfactory, especially if hardened by spray quench to counteract small variations in the steel. Owing to the difficulty of obtaining a steel of this kind of uniform and proper quality in the open market, the author is inclined, however, to recommend for general carburizing purposes a steel with 0.30 to 0.50 per cent chromium. For parts subjected to a very severe service, steels with higher content of alloys such as chromium, nickel, and vanadium, can be recommended, although for ordinary purposes are out of the question owing to the higher price. A slight percentage of chromium, such as suggested, would give a steel of good carburizing properties; as it is very unusual to find a chromium steel with abnormal properties, would not raise the price very much, would rather help than impair the machining qualities, as straight S.A.E. 1020 steel often tears under the tools on account of being too soft, would increase the rate of penetration in the carburizing somewhat, would be beneficial for the hardening, and, last but not least, would necessitate carefully deoxidized heats, as otherwise so much chromium would be lost in the furnace that the chromium content in the finished steel is likely to be lower than specified.

The writer would finally call attention to the important fact that this influence of oxides in steel is not restricted to carburized low-carbon steel only. They will, if present, materially influence the results obtained in heat treating and hardening of any steel. In the preceding, the probable influence on grain size and structure of work submitted to tough annealing operations, and on the spheroidizing of the cementite in annealing high-carbon steels have been mentioned. It is an interesting fact that by carburizing high-carbon steels so as to obtain a carbon content of 1.10 per cent or over, a very sensitive test on the degree of deoxidation is obtained, and that in several instances it has been possible to prove by this method that failures in hardening were due to the presence of oxides in the steel. A well-deoxidized, high-carbon steel should give the structure described as normal in this paper, while abnormal properties are revealed mainly by irregular grain size. Figs. 51 and 52 show, for instance, the edge of two carburized pieces of spring steel, the first of which was reported to have given excellent results in heat treating, while the results with the latter were erratic and irrgular. The two steels were of approximately the same analysis, with the same physical properties, and with no difference in the microstructure before carburizing. Several similar instances could be given, with the results agreeing closely with the record of service for the different steels.

In conclusion, the writer wishes to express his sincere gratitude for the interest, help, and advice extended him by Mr. M. T. Lothrop of the Timken Roller Bearing Company and Mr. H. W. McQuaid of The National Pressed Gear Co. He is also grateful to Prof. E. D. Campbell of the University of Michigan, Ann Arbor, for valuable advice, and to Prof. H. M. Boylston of The Case School of Applied Science, Cleveland, for important steel samples.

HEAT TREATING IN LEAD

By R. B. Schenck

Abstract of Paper

The lead pot furnace has, in recent years, been applied to volume production in steel treating with considerable success. While molten lead is far from being an ideal heating medium, it is the only metal which can be successfully employed for this purpose; and in comparison with the salts in commercial use as bath materials, it has the advantage of a much wider range of working temperature and a much higher heat conductivity. These two properties permit the use of lead in units of very large capacity for temperatures of 650 to 1700 degrees Fahr., thus covering the hardening and tempering ranges of nearly all commercial steels.

The selection of pot materials, the design of the pots and brickwork, and the method of firing are points of prime importance and must receive considerable attention if efficient operation is to be obtained. The unit should be built for the job it is intended to handle, bearing in mind at the same time the desirability of standardization.

While some parts cannot be treated efficiently in lead, there are many which can be handled very successfully. Axle shafts, transmission gears and many smaller parts are now being hardened from lead pots, and a greater number are being tempered in lead. The lead furnace has its greatest range of usefulness for tempering operations, and many parts can be tempered in lead which cannot be efficiently quenched from this type of furnace.

Comparing the lead pot with the oven furnace from the standpoint of operation cost, a great deal depends on the nature of the work handled, but in general, it can be stated that for hardening, the oven furnace is the cheaper of the two, and for tempering, the costs are slightly in favor of the lead pot.

Taking everything into consideration, the greatest argument for the lead pot furnace is the high quality of the treated product resulting from uniform and accurate temperatures. It is very difficult, if not impossible, with an oven furnace to obtain the degree of uniformity which exists throughout a lead pot. Experience covering a period of years has proven, at least to the author's satisfaction, that where conditions permit of its use, the lead pot can produce consistently better work than any other form of heating unit.

A paper to be presented before the Detroit Convention Oct. 2-7. The author, R. B. Schenck, is metallurgical engineer, Buick Motor Co., Flint, Michigan.

THE use of molten lead as a heating medium dates back many years. In the old days the lead pot was a relatively unimportant unit in the hardening room, being used principally for special work where local hardening or tempering was desired. Today, however, this type of furnace has assumed a more prominent place in the industry, and has been applied to volume production with considerable success.

The ideal liquid heating medium would have certain definite physical and chemical properties. It would be low in price, non-poisonous, free from moisture and any tendency to absorb it, high in heat conductivity, low in electrical conductivity, high in specific heat, low in specific gravity, would not adhere to the work, and would have a total working temperature range of 300 to 2400 degrees Fahr., throughout which it would be stable in composition and chemically inert with respect to the atmposphere, the work to be treated, the various alloys used for pots and the commercial refractories.

There are logical reasons for each of these properties. The desirability of low price and non-poisonous qualities is self-evident. Permanent freedom from moisture is highly desirable for reasons with which we are all familiar. High heat conductivity insures more uniform temperature throughout the bath, resulting in better quality of work, larger production, and longer life of the pots. Low electrical conductivity permits electrical heating by internal resistance, which is advantageous for very high temperatures. High specific heat prevents large temperature drops when cold steel is introduced, thus maintaining better thermal stability. Low specific gravity permits the work to sink in the bath, thus making it unnecessary to use special fixtures to insure complete immersion. The specific gravity is also an important consideration in connection with cost, as all such materials are purchased by weight and used by volume. A tendency to adhere to the work causes mechanical loss of the bath material, and in some cases considerable expense due to the necessity of cleaning. A total working range of 300 to 2400 degrees Fahr. would permit the use of this ideal bath material for the treatment of all steels, including high speed steel. Changes in composition, or breaking down under heat, which takes place in some compounds, forming a sludge in the bottom of the pot, greatly interferes with efficient operation. Oxidation by the air either aids in this breaking down, or forms dross with its attendant evils. Chemical attack on the work and on the pot results in injury to the former due to decarbonization and scale, and decreases the life of the latter. Chemical action on the commercial refractories causes destruction of the brick work in the combustion chamber when leaks occur in the pots.

Commercial Bath Materials

The various bath materials in commercial use fall into two classes: metals and salts. Of all the metals, lead is the only one which offers itself for serious consideration. It is relatively low in price, non-poisonous if properly handled, permanently free from moisture, high in heat conductivity, high in electrical conductivity, low in specific heat, very high in specific gravity, does not adhere to the work unless impure or oxidized on the surface, has a total working temperature range of 650 degrees to 1700 degrees Fahr., is oxidized readily by the air at all temperatures when molten, and while the metal itself has little chemical action on the work and pots, its oxide, which always forms to some extent, does attack them, especially at high temperatures. It has a strong slagging action on the acid refractories, and causes rapid deterioration of the brick-work if much of it gets into the combustion chamber.

While it is not the intention in this paper to cover in detail all of the

various liquid heating madiums in use, a brief discussion of the more important ones and their properties in comparison with lead, may be of interest. The principal salts in commercial use as bath materials are the cyanide, chloride, carbonate, and nitrate of sodium. The cyanide, chloride, and nitrate of potassium were also formerly employed for this purpose, but on account of their higher cost have been largely replaced by the sodium salts. Sodium hydroxide, barium chloride and calcium chloride are of less importance, although they are in use to some extent. In some cases the bath is composed of a single salt, but generally two or more are mixed in certain proportions depending on the properties desired.

The salts and salt mixtures in most common use fall into three classes: the high cyanide mixtures, the low cyanide mixtures, and sodium nitrate. The first two are used in the hardening range and the third in the tempering range. For convenience we will classify as high cyanide mixtures those containing 40 per cent or more sodium cyanide, and as low cyanide mixtures those with less than 40 per cent of the cyanide salt. In the first classification we have the commercial products known as "96-98 per cent Sodium Cyanide," "73-76 per cent Cyanide chloride," and a number of mixtures containing sodium chloride and sodium carbonate as well as sodium cyanide. These mixtures, especially the one known as "73-76 per cent Cyanide-chloride," are largely used for cyanide case-hardening, although some of them are employed merely as heating mediums, the case-hardening effect not being especially desired. Those coming under the second classification are used almost entirely as simple heating mediums. They are made in a great number of different compositions, and almost always contain both sodium chloride and sodium carbonate in addition to the sodium cyanide, which sometimes runs as low as 1 per cent. The third class, which is of less importance, comprises sodium nitrate. Although this salt seems to be about the best for low temperature work, its heat conductivity is so low that its use is limited to small units operated at low output.

Practically all the commercial salt bath materials are cheaper than lead in first cost per unit of volume. Their ultimate cost compared with lead is an entirely different matter, and depends on a number of factors. All of the salt mixtures containing cyanide are extremely poisonous and must be handled accordingly. They will all pick up moisture, and should be shipped and stored in air-tight containers. Their heat conductivity is much lower than that of lead, sodium nitrate being by far the worst in this respect. They are low in electrical conductivity, high in specific heat and low in specific gravity. Steel sinks readily in all of them. They all adhere to the work, which results in large mechanical losses, but due to their solubility in water the work is easily cleaned. None of them have the flexibility of lead in temperature range. The cyanide mixtures have a working range of about 1300 to 1700 degrees Fahr., varying with their composition, and sodium nitrate a range of about 700 to 1100 degrees Fahr. The cyanide mixtures continually lose cyanogen and if the content of NaCN is too low will form a sluggish bath accompanied by a sludge in the bottom of the pot. It may be that both of these actions are due, in part at least, to oxidation by the air. The cyanide mixtures, with the exception of their carburizing action, do not attack steel or iron, unless they are too low in cyanide, in which case they have a tendency to decarbonize the work and corrode the pots. They have a detrimental effect on pots made of the nickel-chromium alloys regardless of the cyanide content. All the commercial salt bath materials tend to slag the acid refractories, although they are not as bad as lead in this respect.

Lead

The two outstanding properties of lead, which make it greatly superior to the salts as a heating medium for large production, are its very high heat conductivity and its wide working range of temperature. The salts have their field of usefulness, but they are necessarily limited to small units operated at a comparatively low output.

In purchasing lead for use as a bath material the ordinary grade of pig lead known as "Prime Western" seems to be as good as any, although some of the metal companies have special grades for this purpose which they claim will give better results. Cases have arisen where trouble caused by lead sticking to the work has been traced to a small content of tin, the lead used having been refined from dross, and the tin accidentally introduced in the refining operation. In most cases, however, when a complaint comes from the hardening room that the lead is no good and they cannot keep the work clean, a little investigation will show that the pots have not been properly covered or the covering itself is at fault.

Pot Materials

Lead pots are generally made of cast iron, cast steel or one of the special heat-resisting alloys. Cast iron is used mostly below 1300 degrees Fahr., while steel and the special alloys are employed for the higher temperatures. Ordinary cast iron, does not, as a rule, stand up well above 1300 degrees Fahr., although with very slow firing, it has been known to give good service at 1400 degrees Fahr. The special alloys are generally composed of nickel, chromium, and iron, and some of them are very high in price. The most expensive alloys cost ten or twelve times as much as cast steel per pound, and it is usually necessary that these high priced pots have a life of several thousand hours in order to compete with steel pots. The determining factor is the ultimate cost of the whole heating unit per ton of treated work, which takes into consideration such items as fuel consumption, maintenance of the brick work and shut downs.

Pot and Furnace Design

The design of the pot is of prime importance. The corners should be properly rounded, and the thickness of the sides and bottoms worked out for the best economy. There is considerable difference of opinion throughout the industry in the matter of pot design, some favoring very thick bottoms with thin or tapering side walls, and others thin bottoms with side walls of the same thickness. The material of which the pot is made is an important consideration in connection with design, the nickel-chromium alloys, in most cases, requiring lighter sections. As in the case of selecting the proper material, the design must be figured out on the basis of ultimate cost. A pot with very thick walls and bottom may last much longer than a lighter pot, but when all the various factors are taken into consideration, the lighter one may prove to be the more economical of the two.

Second in importance to the design of the pot is that of the brickwork. Direct flame impingement on the pot is, of course, fatal, and every effort should be made to avoid it. The so-called "return flame" method of firing shallow rectangular pots with a single burner, in which the flame travels from one end of the combustion chamber to the other and back again, gives excellent results. In this type of furnace the pot hangs by the flange, the bottom of the pot forming the top of the combustion chamber, which is divided longitudinally into two parts by a brick wall having an opening at the end opposite the burner. The long flame obtained in this way gives very uniform heating

and high thermal efficiency. This construction can be used for either gas or oil fuel, but is especially advantageous when using oil, which has more of a tendency to cause localized heating. In all except the smallest units the outer walls consist of 9 inches of fire-brick without any special insulation. Insulating brick would do very little good as the heat losses through the walls are negligible compared with those from the surface of the lead. The height of the combustion chamber when firing with oil should not be less than 10 inches. The burner should be fastened rigidly in the proper position so that it cannot be pointed upward toward the pot. With some oil burners a splash brick is not necessary, but the usual type requires one, and for this purpose an ordinary standard fire brick placed with the 2½ x 4½ inch face toward the burner answers every requirement.

With the above furnace the brick work is very simple in construction, cheap and easily repaired. A shallow rectangular pot of any size can be fired in this way, and it is needless to point out the advantages of the single burner as compared with two or more. Attempts have been made to protect the pot by building a brick arch between the pot and the combustion chamber, but this construction tends to reduce the rate of heating, lowers the thermal efficiency, and stores up a large amount of heat which interferes with temperature control. An added objection is the rapidity with which the arch burns out necessitating frequent repairs. It is probable that any increase in the life of the pot resulting from this arrangement could be obtained without the arch construction by simply reducing the rate of heating to the same point as with the arch.

Deep pots, such as are used for hardening camshafts, are generally round, although some square ones are in use. The round ones are set in either a round or square brick work, and are usually tangentially fired by two or more burners placed at different levels. If square in section they are set in a square brick work and fired in a similar manner. Deep pots are not often hung from the flange, the general practice being to stand the pot on a pier in the bottom of the combustion chamber. Pots of considerable depth are expensive to install, as they have to be set in a pit in order to have the top at the correct working height, or the operators have to work on an elevated platform. Due to the small surface of lead exposed to the air, and the large side wall area, insulating brick can be advantageously used in this type of furnace, which is not the case with the shallow pot furnaces as explained above.

Protective Coverings

Lead, on account of its tendency to oxidize at all temperatures when molten, the rapidity of oxidation increasing with the temperature, must be covered with some protecting medium. Without a suitable covering, the lead loss is excessive, and the work comes out covered with oxide and metallic lead which are often very difficult and expensive to remove. Wood charcoal, corncob charcoal, charred nut shells, charred leather, coal coke and petroleum coke are some of the materials in commercial use as pot coverings. Hard wood charcoal, size No. 3, such as is used in the manufacture of carbonizing compound, is one of the best, but is not always the most economical. A great deal depends on the nature of the work and the temperature of operation in determining the most suitable covering. In hardening transmission gears the best covering obtainable is, as a rule, none too good, while in hardening axle shafts coal coke or the cheapest grade of charcoal screenings will answer the purpose, providing the tempering treatment is also performed in lead.

The action of the carbonaceous coverings is both chemical and mechanical, their efficiency depending to a great extent on the rapidity with which they burn, and the temperature at which burning starts, sometimes called the kindling teperature. The chemical action is due to the reducing effect of CO gas which is generated by the combustion of the covering. Below the kindling temperature no CO is generated and the protective effect becomes entirly mechanical. Coal coke has such a high kindling temperature that it is practically useless in the tempering range, although it makes a good covering for some classes of work in the hardening range. Wood charcoal has a much lower kindling temperature, somewhere in the neighborhood of 850 degrees Fahr. Although the tendency of lead to oxidize increases with the temperature, it will give a great deal more trouble at 800 degrees Fahr. than at 950 degrees Fahr., when wood charcoal is used.

An interesting example of this occurred in tempering axle shafts. These shafts had been treated at 950 degrees Fahr. in a large lead pot using a wood charcoal covering, and practically no trouble was experienced from lead sticking to the work. Due to a change in the steel the temperature was lowered to 800 degrees Fahr., and trouble started at once. The shafts were so dirty that it cost in the neighborhood of fifty dollars a day to clean them, and although other coverings were tried and the lead skimmed more frequently, the results were just as bad or worse. The trouble was finally overcome by dipping the shafts in molten caustic soda immediately following their removal from the lead, and then quenching them in water. The result was perfectly clean work and a considerable saving in lead, several tons being recovered from the caustic soda pot each month. This process has been in use for some time and has saved a great deal of trouble and expense. The caustic soda pot is held at a temperature of about 775 degrees Fahr. which maintains good fluidity, and is low enough to prevent the chemical action which this salt exerts on the pots at higher temperatures.

The size of the covering has a great deal to do with its effectiveness. The most efficient size seems to be that of No. 3 charcoal, and this applies to all the various materials. Large lump charcoal is no good at all, and if purchased in this form it has to be crushed. Dust is unpleasant to handle and packs so closely that the generation of CO is slowed down at the lower temperatures.

Depending on the nature of the work, the kind of covering employed, and the temperature of operation, the bath must be skimmed more or less frequently. The coverings burn to an ash which settles on the surface of the lead and interferes with the action of the CO gas. Moreover, the protective effect is never perfect and a certain amount of oxide will always form, even under the best conditions. This ash and oxide must be removed and replaced with new material every so often or trouble will result.

Molten salts have been tried as coverings but with rather indifferent results. Caustic soda will work well at the start when used at low temperatures, but there is a gradual accumulation of lead oxide which soon causes trouble. Sodium nitrate is still worse due to its strong oxidizing effect. Mixtures of sodium and calcium chlorides have been used as coverings at temperatures as high as 1650 degrees Fahr., but they tend to break down and form a sludge, and although the work comes out perfectly clean, they are very expensive due to the large quantity consumed. Another objection is the necessity of melting these mixtures in a separate pot and adding them in the molten condition to the lead. They also tend to decarbonize the work, which, in some cases, is very troublesome. Of all the salts, the cyanide

mixtures are the best for high temperature work, but they are so expensive compared with the solid coverings, that their use is rather limited. The protective action of salt coverings is entirely mechanical except in the case of those containing cyanide. As long as no oxidation takes place very little lead adheres to the work, and if the work is water quenched the explosive effect when the adhering salt strikes the water removes the last traces of lead. A very decided objection to the use of salt coverings on large pots is the great amount of heat radiated from the surface of the bath, which results in bad working conditions for the operators, and undoubtedly lowers the thermal efficiency of the unit. The solid coverings have a marked blanketing effect which is almost entirely absent with the salts.

Methods of Operation

Lead pot furnaces can be operated by either the batch or continuous methods. For tempering, the former is by far the most satisfactory, while for hardening, both methods are successfully employed. In using the batch method, the pot is filled to its full capacity and the work completely removed as soon as the desired temperature is reached. It is generally necessary to shut off the burner before removing the work, but in some cases, if charging and drawing are sufficiently rapid, the burner can be allowed to remain open. With the continuous method, the bath is held at the desired temperature, part of the load being removed and replaced with cold work at certain intervals.

In hardening axle shafts, continuous operation has given very satisfactory results. A large oil fired installation operated in this way consists of a twin furnace, the two pots being placed side by side and fired independently of each other. The twin construction lowers the installation cost, saves floor space, and reduces the heat losses. The shafts are handled from the end of pot, suitable fixtures being provided to hold them under the lead. The return flame method of firing is employed, the burner being placed at the end opposite the operator. The pot which is made of nickel-chromium alloy, is rectangular in form, and has a lead capacity of 3600 pounds. The temperature control consists of recorder, deviation meter, and signal lights, set for an operating range of 1500 to 1530 degrees Fahr. A timing device controls a light which flashes every 1½ minutes, this being the signal for the operator to quench a certain number of hot shafts and replace them with cold ones. The hot shafts are removed from the side of the pot next to the quenching tank, those remaining in the bath moved over, and the cold ones placed in the opposite side, thus insuring a certain definite time of heating. For shafts up to 1⅜ inches in diameter, 4½ minutes of heating is sufficient. With this furnace it is possible to handle 1500 pounds of steel per hour in each pot.

A similar insatllation for hardening transmission gears is operated by the batch method. In this case the pot, which is the same as those used for axle shafts, is installed as a single unit, and the work is handled from the side, the gears being held on hooks and suitable fixtures. After a cold charge of gears is placed in the bath, the burner is turned on full, and then shut off when a certain temperature is reached, the bath being allowed to "drift" to the required temperature. The output of this unit is about 1000 pounds per hour. The batch method is employed in this case because of the effect of longer heating in preventing distortion of the work.

The installation previously mentioned for tempering axle shafts, consists of a rectangular pot of 8000 pounds lead capacity capable of handling better

than 3000 pounds of steel per hour. This unit is fired with a return flame, and is operated by the batch method. The pyrometer equipment includes a recorder, deviation meter, and signal lights. A load consisting of 200 axle shafts is charged and the burner turned wide open. At 750 degrees Fahr. the burner is closed and the temperature allowed to "drift" the rest of the way. The desired temperature is 800 degrees Fahr., and it has been found by experience that this unit has a 50 degree "drift." As soon as equilibrium is reached the shafts are removed and dipped in a caustic soda pot, and then water quenched to remove the adhering lead. The work is not removed from the pot until the temperature has become stationary, thus insuring uniformity throughout the whole bath. A number of these units are also in use for tempering propeller shafts, crankshafts, front axles, steering knuckles, connecting rods and numerous other parts. During the war crank shafts for the Liberty Motor were handled in a furnace of this type.

Thermal Efficiency

The thermal efficiency of a lead pot furnace increases very rapidly with the output, and for this reason it is highly desirable to operate as near as possible to maximum capacity. In this paper the efficiency will be expressed in pounds of steel heated to the desired temperature per gallon of oil consumed. A test on a unit of 3000 pounds lead capacity working on axle shafts at a temperature of 1500 to 1520 degrees Fahr., and fired with a return flame, gave an efficiency of 136 pounds per gallon at an output of 1200 pounds per hour. The same pot fired without the return flame gave an efficiency of 98 pounds per gallon at the same output. Further tests without the return flame showed efficiencies of 88 and 128 pounds per gallon at outputs of 1022 and 1532 pounds per hour respectively. These figures illustrate the increase of efficiency with output and the superiority of the return flame method of firing.

A further test was made on the same unit in which the pot was fired by the return flame method, and the air for combustion was preheated by the waste gases. The preheating was accomplished by passing the air through a steel pipe surrounded by the products of combustion in a long flue. With the air preheated to 700 degrees Fahr. and an output of 1094 pounds per hour, the thermal efficiency was 175 pounds per gallon.

Very high efficiencies can be obtained by preheating the work in an auxiliary pot heated by the waste gases. A test was made on an equipment of this sort, in which the two pots were built into the same brickwork and placed side by side, the flame traveling the length of the high heat pot, through an opening in the dividing wall, and back under the preheat pot to the vent. The pots were of the same dimensions as those in the tests just described. The high heat pot was run at 1500 to 1520 degrees Fahr., the preheat pot adjusting itself to a temperature of 1000 to 1100 degrees Fahr. The work, which consisted of axle shafts, was handled by the continuous method, several shafts being quenched at stated intervals and replaced by the same number from the preheat bath, these in turn being replaced by cold ones. With outputs of 968 and 1607 pounds per hour, respective efficiencies of 182 and 248 pounds per gallon were obtained. In operating this unit without the preheating pot, an output of 1086 pounds per hour gave an efficiency of 104 pounds per gallon. To bring the high heat bath up to 1500 degrees Fahr. on Monday morning, after standling idle over the week-end, required 10.04 gallons of oil, and to hold it at this temperature whe no work was being put through, required 1.69 gallons of oil per hour. The above installation, while capable of extremely high thermal efficiency, was not economical from the

standpoint of labor cost, as the shafts had to be handled twice, thus requiring two operators instead of one. The increased labor cost was much greater than the saving obtained through lower oil consumption.

Lead Consumption

The amount of lead consumed in lead pot furnaces varies greatly, and is dependent on the temperature of operation, the frequency with which the pots fail, the size of the unit, the nature and quantity of the work handled, the kind of covering used, and the care exercised in keeping the bath clean and properly covered. In general, the lead consumption should not run over .5 pounds per 100 pounds of steel heated. This figure tends to increase at the higher temperatures on account of the greater ease with which the lead oxidizes, but because of the increased chemical activity of the covering, the difference is less than might be supposed. Also, at temperatures below the point at which the generation of CO commences in the covering, the consumption of lead is generally very high. The figure given above does not, however, represent a total loss, since the dross and skimmings have a marketable value.

The consumption of the carbonaceous coverings varies somewhat depending on a number of factors. An extensive test on a pot handling axle shafts at 1500 degrees Fahr., and using a charcoal covering, showed a consumption of 1.23 pounds of charcoal per square foot of bath surface per hour. Under the same conditions with a coke dust covering the consumption was .96 pounds. A large tempering pot handling axle shafts and other parts at temperatures of 950 to 1050 degrees Fahr. showed a charcoal consumption of 1.16 pounds.

A test on a pot using a salt covering consisting of half and half sodium and calcium chlorides, and operating on axle shafts at 1500 degrees Fahr., showed a salt consumption of about .3 pounds per square foot of bath surface per hour. Expressing this in terms of weight of shafts handled, the consumption was about 2 pounds of the salt per 100 pounds of steel. The latter figure is preferable in this case, as the salt loss is entirely mechanical and depends on the amount carried away by the steel.

Cost Considerations

In considering the question of cost, there seems to be a prevalent opinion throughout the industry that lead pot furnaces are very much more expensive to operate than those of the oven type. While this is true in many cases, there are some jobs which can be handled in lead at an appreciable saving. The lead pot generally gives its greatest economy when used for tempering operations on parts such as axle shafts, which can be easily handled in bulk. For such work, the labor cost can be reduced to a figure comparable with that obtained in any other type of furnace. Large tempering pots, such as those previously described, can be installed for less than 20 per cent of the cost of an equivalent capacity in oven furnaces. Moreover, the lead furnace occupies but a fraction of the floor space required for the same oven furnace capacity. Installation cost and floor space occupied are important items, as they are represented by definite overhead charges. Large tempering pots also have the advantage of lower fuel consumption. A general comparison from the cost standpoint shows the lead pot furnace, when used for tempering, to be more economical in fuel consumption, first cost, occupied floor space, and the necessary overhead charges for the last two items; while the oven furnace has in its favor the item of low maintenance, taking into consideration the consumption of pots, lead, and coverings for the lead unit.

For hardening work, the operating cost of the lead pot does not compare so favorably with that of the oven furnace. The former occupies a smaller amount of floor space, and the first cost is usually less, but the maintenance cost is much higher. The lead pot can be operated at higher fuel efficiency by preheating the air for combustion, but ordinarily the fuel cost is about the same in both furnaces. The labor cost varies greatly with different jobs, but is generally higher with the lead furnace.

In spite of the usual higher cost of the lead hardening operation itself, it is sometimes possible to effect a saving by this method through the elimination of pickling or rattling, and by treating after the machine work is done. Axle shafts which are too hard for commercial machining after heat treatment, and which must be held accurately to size, can be treated in lead after machining with excellent results. Large quantities of shafts are being handled in this way at what is believed to be a lower total cost than by any other method.

Conclusion

Taking everything into consideration, the greatest argument for the lead pot furnace is the high quality of the treated product resulting from uniform and accurate temperatures. It is very difficult, if not impossible, with an oven furnace to obtain the degree of uniformity which exists throughout a lead pot. Experience covering a period of years has proven, at least to the author's satisfaction, that where conditions permit its use, the lead pot can produce consistently better work than any other form of heating unit.

(*Continued from page* 1110)

quantity of steel involved justifies the expense, it is possible to select the most suitable structure with great exactness. When there are a number of different machining operations to be performed upon the same steel, it is usually necessary to adopt a compromise structure which is fairly well suited to all the operations. It will usually be found that this structure which best satisfies the requirements of all the different operations will be one of ferrite, spheroidized cementite and pearlite in which only a small percentage of lamellar pearlite remains, as shown in Fig. 13.

(*Continued from Page* 1176)

all of them appeared to be brittle, though fine-grained. At low magnification, ghost lines were prominent (Fig. 28), and at 1000 diameters (oil immersion) the structure proved to be a sorbo-troostite (Fig. 29.) The carbon, manganese, and chromium content exceeded the specification by 0.02, 0.16, and 0.20 per cent, respectively. It was concluded that the high combined content of hardening elements made a steel unsatisfactory for the severe torsional stresses in heavy duty springs. A higher drawing temperature to counteract to some degree the excess of hardening elements would have produced a more satisfactory structure.

STANDARDIZATION OF METHODS LEADING TO COMPARATIVE PHYSICAL PROPERTIES OF ALLOY STEELS

By R. M. Bird

TODAY, as never before, designers, material engineers, consumers and producers are concerned with the relative values of alloy steels. The decision as to the type of steel to select for a given part is often not easy to reach. The man, upon whom rests the responsibility of making the decision, has to consider many things; primarily, the ultimate service of the finished part, frequently its forgeability and machinability; availability of stock, and always its cost.

For heat treated parts he is concerned with the physical properties which can be regularly secured; not, after fussy laboratory heat treatments, but obtainable, within reasonable limits, in a modern heat treatment shop. For alloy steels this latter consideration, balanced against cost, is usually the deciding factor.

Dependable information on this subject heretofore has not been generally available, and many incorrect selections, due to insufficient or inaccurate data, have led to disastrous results. What we all want, and particularly we of the American Society for Steel Treating, is authentic and comparable data of this kind especially for small bars up to 1½ inches in diameter, with information as to how to change our treatments for large and irregular sections, and how much less to expect of the physical tests from these large sections as compared with the small bar considered as a base.

The work of the Steel Standards Division of the Society of Automotive Engineers has, in the writer's opinion, been the biggest factor in standardizing alloy steels; and their respective physical property charts and recommended heat treatment practices (which, after their intensive work over the last two years, will soon be available) will be of considerable help to everybody. Later, upon these charts as a base, will undoubtedly be built more information as to what to expect from larger sections.

At the Bethlehem Plant of the Bethlehem Steel company, we have been accumulating data of this sort for many years. Shortly after the Armistice, in an effort to reduce to a minimum all controllable variables affecting final results, and to reduce our comparisons to a common small bar base, we put into routine operation a system which yields more consistent and, therefore, more truly comparable results than any previously familiar to us. Perhaps a description of our procedure may be of general interest.

First, let me emphasize the fact that we guard against, at all times, so called "laboratory results." The aim is to secure final figures which are a guide to results produceable under good commercial heat treating practice.

For all standard alloy analyses under manufacture and for special steels of unusual analysis, a 4 x 4-inch billet, located well down in the ingot, is selected from such heats coming through the mill as are rolled to this section. For each analysis this procedure continues until billets have been secured from not less than three, and frequently from five different heats. A 30-inch length of each billet is sent to the laboratory and etched with hot hydrochloric acid on each end. The etchings must show no segregation or

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A paper presented before the Indianapolis Convention of the Society. The author R. M. Bird is Engineer of Tests, Bethlehem Steel Company, Bethlehem, Pa

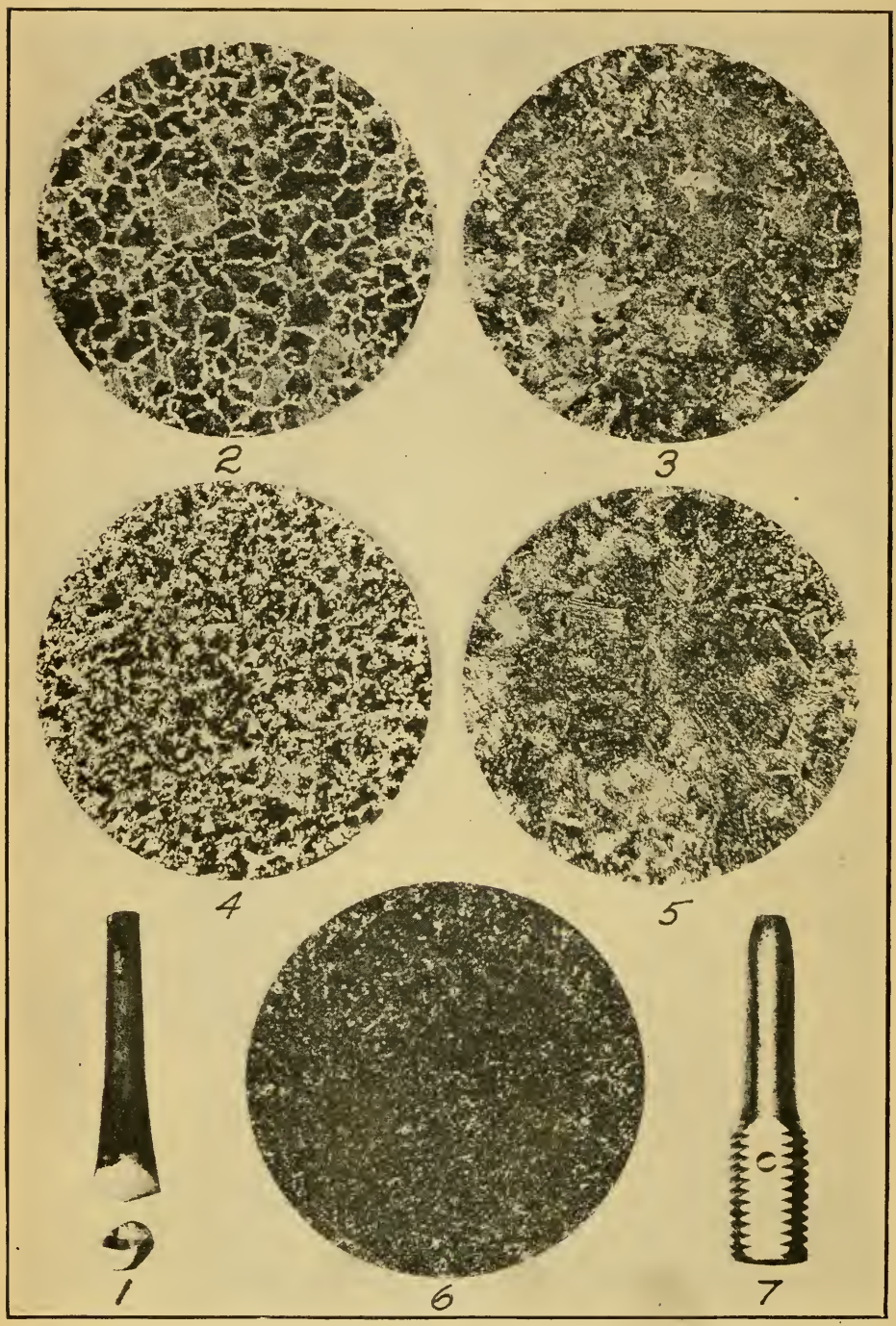

Fig. 1 Drill and specimen which has been sampled for chemical analysis. Fig. 2 Photomicrograph showing a satisfactory structure after quenching and tempering. Fig. 3 Photomicrograph revealing excessive segregation. Such a specimen would be rejected. Fig. 4 Shows the microscopic structure of a specimen which was quenched at too low a temperature. Fig. 5 Shows the microscopic structure of a specimen which was quenched at to high a temperature. Fig. 6 Photomicrograph of a specimen quenched at the proper temperature. Fig. 7 Tensile test specimen with Brinell impression on ground surface.

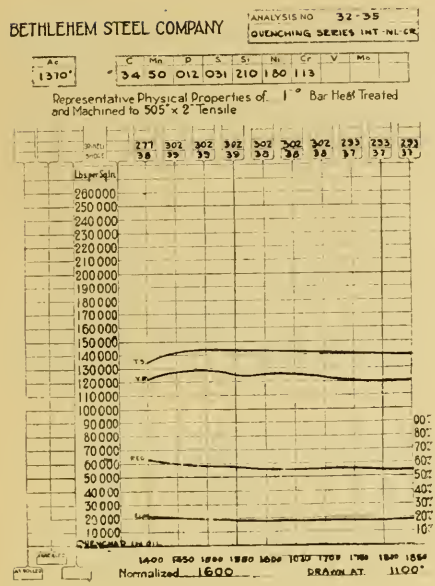

Fig. 8 Representative physical property chart of 1 inch round bar of chrome nickel steel normalized, quenched in oil and drawn. Quenching temperatures used as variable. Standard tensile test specimens were used.

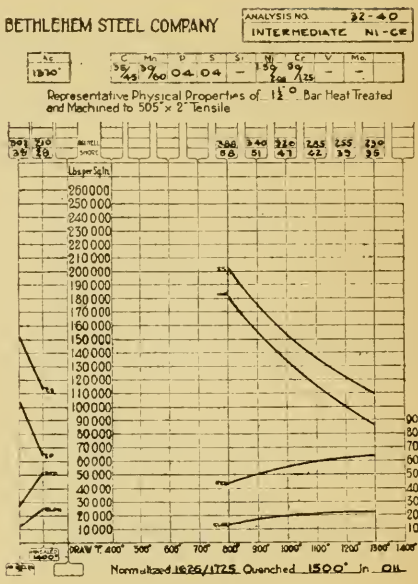

Fig. 9 Representative physical property chart of 1½ inch round bar of chrome nickel steel normalized, quenched in oil and drawn. Drawing temperatures used as variable. Standard tensile test specimens were used.

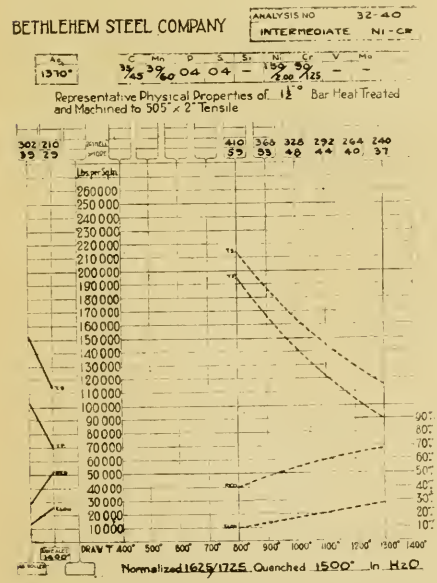

Fig. 10 Representative physical property chart of 1½ inch round bar of chrome nickel steel normalized, quenched in water and drawn. Drawing temperatures used as variable. Standard tensile test specimens were used.

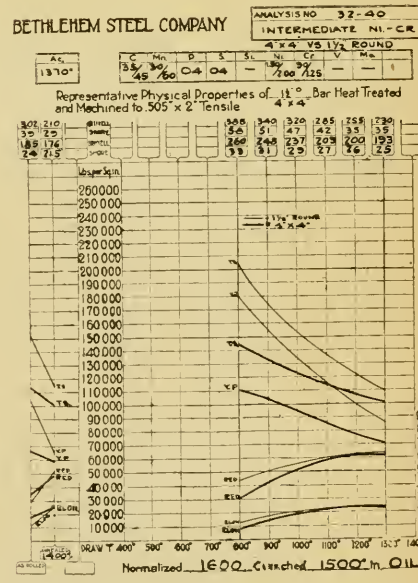

Fig. 11 Representative physical property chart of 1½ inch round bar compared to 4 x 4 inch billet of chrome nickel steel normalized, quenched in oil and drawn. Drawing temperatures used as variable. Standard tensile test specimens were used.

excessive slag. The adjacent billet is then rolled to 1 inch round and sheared to mill lengths. The ends of these bars are polished and examined under the microscope, and, when accepted, are inspected for surface cracks and seams. From the acceptable 1 inch rounds check chemical analyses are run on drillings taken radially with a taper point drill, of width greater than 1 inch, to a sufficient depth so that the drillings shall represent a full half area of section. Fig. 1 shows a drill and the specimen which has been sampled for chemical analysis. Simultaneously, critical point determinations are run on a standard transformation point apparatus. The general characteristics of the curves and the definite AC points are recorded.

The 1 inch rounds are then normalized or annealed by heating in whatever large hollow forging may be coming through the annealing furnaces at the time, to a temperature of usually 1650 degrees Fahr., followed by air or furnace cooling as the requirements of the container forging may demand.

Table I

Results From Longitudinal Specimens Taken Midway Between Axis and Surface of 4 x 4 inch Section Showing Expected Results Expressed in Percentage of Results from 1½ inch Round Bars as Shown in Fig. 11

	Drawing Temperatures					
	800	900	1000	1100	1200	1300
	Per cent					
Tensile Strength	72	75	80	82	89	91
Elastic Limit	61	67	71	74	78	82
Reduction Area	70	84	95	98	102	102
Elongation	69	81	100	110	110	113
Brinell	76	84	78	85	85	90
Scleroscope	77	84	81	81	82	86

To determine the proper quenching temperature, 5-inch lengths are heated in an electric furnace to temperatures ranging from below the known critical point, increasing by 100 degree Fahr. increments, to usually 1700 degrees Fahr. Each piece is held one hour at heat and, when cracking is not expected, is quenched in water or otherwise, in oil. The time consumed in transferring the specimens from the furnace to the quenching bath is approximately 20 seconds. Both water and oil tanks are sufficiently large so that the temperature of the bath is maintained between 70 and 85 degrees Fahr. without circulation. Pieces when submerged, either singly on end or separated in a basket, are continuously raised and lowered in the bath until cold. The quenching oil used is the same as in our large heat treatment tanks, being a petroleum oil, single refined, purchased to 340 degree Fahr. flash point, 380 degree Fahr. fire point, 26 to 28 Baume specific gravity, and free from acid.

All specimens of this series are drawn to 1100 degrees Fahr., held one hour, and cooled uniformly in air. Standard .505 inch x 2 inch tensile test bars are machined concentric with center of bar and are pulled in 100,000 pound universal testing machine. Each test specimen is then examined microscopically and the microstructure is then recorded. Decision as to the proper quenching temperature for 1 inch rounds of this stock is based upon a study of the physical property test results, combined with the microscopic report and the observed critical points. Photomicrographs in Fig. 2 to Fig. 6 show a satisfactory structure and four unsatisfactory structures resulting from the heat treatments which were applied.

The wide quenching range found in many alloy steels is surprising. Publicity has been given to this point in connection with chromium molybdenum steels. We find the range equally wide for the chromium nickel steels.

Sometimes we are still in doubt as to the proper quenching temperature. In such cases we quench more samples over a range of 200 degrees Fahr. by 50 degrees Fahr. increments. With the quenching temperature settled, sufficient pieces are prepared to cover a range of draws from 800 degrees Fahr. to

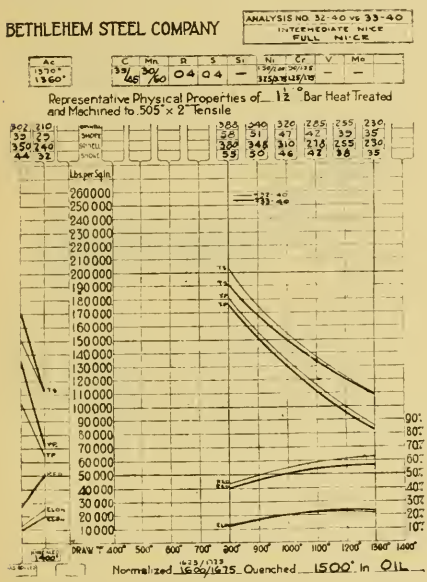

Fig. 12 Representative physical property chart comparing 1½ inch round chrome nickel steels of high and low alloy content. Steels were normalized, quenched in oil and drawn. Drawing temperatures used as variable. Standard tensile test specimens were used.

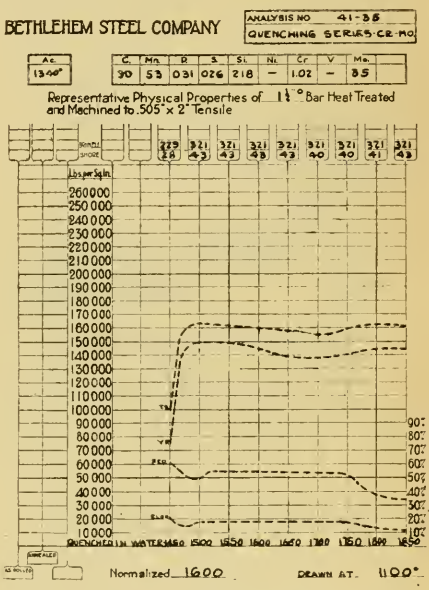

Fig. 13 Representative physical property chart of 1½ inch round bar of chrome molybdenum steel normalized, quenched and drawn. Quenching temperatures used as variable. Standard tensile test specimens were used.

1300 degrees Fahr. by 100 degree Fahr. increments, following an oil quench. A similar series is quenched in water on such analyses as will stand such drastic treatment. Tensile tests from these pieces form the ground work for our chart.

The longer threaded end of each broken test piece is filed and ground on the side to below the bottom of the threads, and Brinell and scleroscope readings are taken on this prepared surface as far as possible from the quenched end. A tensile test specimen so treated and tested is shown in Fig. 7.

The Brinell and scleroscope figures are not influenced by "end treatment," and represent the 1 inch round bar at half radius, resulting in more representative and consistent readings than those secured on or near the surface of the bar as heat treated. The data thus obtained are visualized by plotting upon a chart which, because of its simplicity we have adopted as a standard. As these charts are printed on tracing paper they can be reproduced as blue prints, or vandykes. Furthermore, for convenient comparison of different curves, one sheet can be superimposed upon another. Oil quenched tensile properties are shown as full lines; water quenched results ar dotted. Charts showing the physical properties of several alloy steels are

included under Figs. 8 to 13 inclusive. When three or more separate and distinct sets of curves from as many different heats of a given analysis show the same general characteristics, it is concluded that such physical properties are representative of 1 inch round bars from carefully selected material of that chemical analysis.

Comprehensive data on the effect of size as it influences the physical properties of heat treated steels are not yet available. Figs. 14 and 15 show the effect that mass has upon the physical properties of nickel chromium

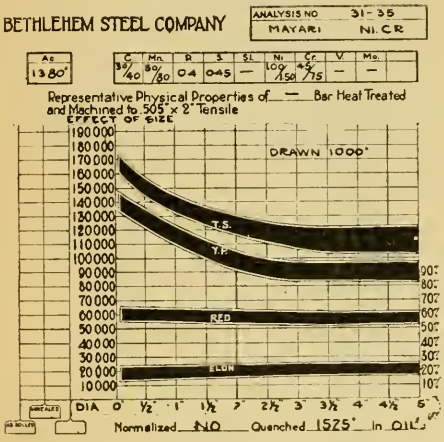

Fig. 14 Representative physical property chart showing the effect of size on the physical properties of heat treated chrome nickel steel using Mayari ore.

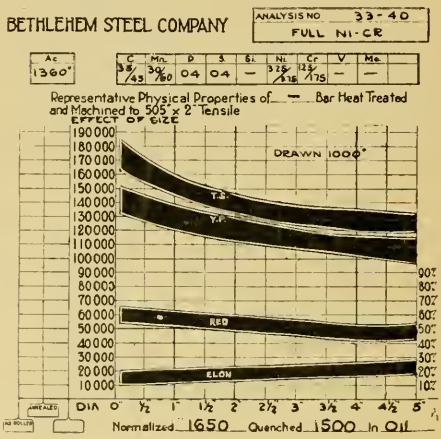

Fig. 15 Representative physical property chart showing the effect of size on the physical properties of heat treated chrome nickel steel.

steels. Excluding abnormally large forgings, seldom specified commercially of alloy steels, it would seem that above 5 inches in diameter or 5 inches square the physical values change but little with increasing size. As the sections decrease, especially under 2 inches, the elastic limit, tensile strength and reduction of area curve up sharply, with a corresponding decrease in elongation.

Paralleling the procedure with the 1 inch rounds, a more restricted series is run on the 4 x 4 inch billets. The selection of 4 x 4 inch sections, which with our operations is a convenient size, represents a point in the curve beyond which the increments of change are small. For these we quench in 11 inch lengths, and locate the test at middle length and at half radius. Table I shows the percentage of the figures shown in Fig. 11 that can be expected at a point midway between axis and surface of a 4 x 4 inch section.

The resulting curves are compared with the 1 inch round charts in two ways:

1st—By superimposing 4 x 4 inch chart on 1 inch round chart.

2nd—By tabulation of percentages of physical properties over the 1 inch round stock as a base.

Conclusion

In conclusion the writer wishes to point out that this paper has been offered with the hope that more thought will be given to the need for what is expressed in the title of the paper—"Standardization of Methods Leading to Comparative Physical Properties of Alloy Steels;" and with the suggestion that the American Society for Steel Treating might well take up this work in its program for the coming year.

THE HIGH COST OF CARBONIZING

By T. G. Selleck

THE use of the carburizing process is, no doubt, greatly restricted because of its excessive cost. There was a time when manufacturers kept aloof from it as much as possible because of its unreliability, but that hindrance to its successful use having been largely removed by more scientific methods of application and the improvements made in shop equipment, such as heat recording and controlling instruments, and closer laboratory supervision, it is found that there is added reason to avoid its use in the increasing cost of application.

This increasing, or at least increased, cost of application is to some extent due to the improvements mentioned, and it may be fairly claimed that the increased cost is offset by the improved quality of the carbonized work produced and saving in the matter of loss of parts, as a result of carburizing failures. But the real cause of the high cost of carburizing lies in certain conditions attending every carburizing operation, whether performed under the most modern methods and with the use of modern equipment, or in the ordinary crude way without scientific supervision.

A Study of Costs

A close study of the process and methods of its application reveals the fact that, in general, the methods employed are decidedly extravagant, from the point of cost, and have attached to them certain "fixed charges" that establish the foundation for excessive cost. These fixed charges are common to all carburizing operations, but only those wherein pots and boxes are used will be considered in this consideration of the subject, since other methods are not used sufficiently to obtain any accurate information as to average costs. These fixed charges are classified as follows:

1. The cost of primary heating; that is, raising the temperature of the cold contents of the pot, or box, to a carburizing temperature.

2. Wear and tear of equipment, or depreciation, except for pots and boxes.

3. Cost of pots, or other containers.

The first item, the cost of primary heating, is combined usually with the second item and calculated as so much per hour per furnace, and the charge allowed averages about one dollar per hour. This also includes labor and will, of course, vary according to the number of furnaces in proportion to labor employed; but one dollar per hour is considered a fair average. The third item must be considered by itself because it is determined according to the character of the metal in the container used, the weight of the container in relation to weight of the parts and the number of hours the container is in service. The cost of primary heating is the heaviest part of all the expense of carburizing a charge of steel parts, since the time required for such heating has proven to be, both by laboratory test and actual shop practice, an average of about 2/3 of the total furnace time; this means that for a twelve hour operation, 8 hours is spent in primary heating and 4 hours given to the application of the desired carburizing temperature.

The causes underlying this excessive fuel cost for primary heating are

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A paper written for TRANSACTIONS. The author, T. G. Selleck, is consulting metallurgical engineer, Chicago, Ill.

found in the manner in which the process is applied and is well illustrated in the specifications sent out recently by a large motor manufacturer seeking quotations on equipment for carburizing steel gears.

Ten single chamber or five twin-chamber furnaces of approximately the following dimensions are required—4 feet wide, 7 feet 6 inches deep and 24 inches to the spring of the arch, from the hearth. These five or ten furnaces, either electric or coal-burning, are to be used to carburize approximately 2200 gears in 12 hours. Each furnace will have a capacity of 15 pots, each pot containing 15 gears, and the specifications say "The charge per pot will be made up as follows:

Cast steel pot	weight 116 pounds
Fifteen gears	weight 37 pounds
Carburizing material	weight 27 pounds
Total weight per pot	weight 180 pounds"

From this it will be seen that 180 pounds of material are to be heated in order to heat 15 gears weighing about 1/5th, or 20 per cent of the total. The estimated time required for primary heating being 8 hours in this case and the estimated cost of furnace operation being $1 per hour, it is apparent that the fixed charge for primary heating in this case is $8 for 555 pounds of gears, or 1.4 cents per pound. The total weight of 15 pots is 2700 pounds and this mass of material must all be heated through before the gears can be affected by the carburizing material: This is what is meant by primary heating and this specification illustrates clearly one of the causes of the high fixed charges in carburizing. More than 3 times the weight of the gears is contained in the weight of the pots alone so that the fuel used during the entire operation is but 1/3 applied to the actual carburizing of the steel even after the primary heating.

The deterioration of pots in this case will amount to 0.55 cents per pot for the 12 hours of actual use or an additional 1.5 cents per pound, and is based upon one thousand hours life of pots and the lowest price at which such pots may be purchased. Thus we have 3 cents per pound in fixed charges in every average carburizing operation for primary heating. To this must be added fuel and labor cost for the actual carburizing period and the regular "overhead" charge to complete the actual cost of carburizing and for the finished product the additional cost of subsequent heat-treatment. These figures are for operations carried out under the most favorable conditions; only in plants where the strictest supervision of furnace practice is maintained can it be hoped to keep these primary costs within the limits given here.

Close Supervision Necessary

In many carburizing plants, sometimes maintained by large corporations, where other manufacturing processes are given close supervision and rigid care in all details, there is found a slackness and indifference that is appalling when the importance of the work being done is considered. Equipment is most shamefully abused and allowed to deteriorate until the production of a uniform and high quality product is impossible. Then it is that trouble presents itself, parts fail under final inspection, or what is worse, in service, and the manufacturer finds it necessary to call in some outside help to locate the cause of his failures. One recent case indicates how the carelessness and indifference of the supervisor of the carburizing and heat treating plant of a very large factory cost his employers a considerable monetary loss besides a

heavy loss in business.

Being called to the plant in an advisory capacity, the writer was amazed to find an utter disregard of the simplest rules of care in the use and treatment of equipment. The carburizing parts being quenched from the pots at a temperature of approximately 1650 degrees Fahr. it is easily understood that a malleable iron pot would be more or less soft and easily distorted by rough handling, and it would seem that provision would be made for handling in such a way as to prevent, as far as possible, the deforming of them. But in this case the pots, as soon as emptied were hurled a distance of at least 10 feet on to a cement floor covered with steel plates; the result was a lot of pots of every conceivable shape with covers in equally bad condition, after only one or two usings. It was partly because of the use of these distorted pots that complaints of failure of their carburized parts in service, a thousand miles away, were coming too frequently to the notice of the manager who finally set about an investigation by a disinterested engineer.

In this plant a cost of 3.5 cents per pound for carburizing was claimed but if the company were obliged to purchase their pots the cost would easily be doubled, but having their own foundry, they were not allowing themselves any profit on them, and thus reckoned their costs below what would be the average. The same abuse of furnaces was noted. Scale from the pots was allowed to accumulate in the furnaces, until the gas flames from the combustion chamber came in streaks, striking some of the pots with a directness and severity that caused over-heating, and so remote from others that the indirectness of the heat caused a lack of temperature that was reflected in scanty penetration of parts contained in them.

These deplorable conditions are due to that most dangerous of all factors employed in carburizing and heat treating "the human element." More than fuel, more than carburizer, more than the checking and calibration of the pyrometer, does this human element need constant watching and checking up, for it is the factor wherein originates every failure that occurs and causes the unnecessary cost that is common in the maintenance of equipment.

Nothing has been said about the cost of carburizer as related to the high cost of carburizing, but if the proportion of carburizer by weight to the weight of steel parts is to be maintained in all cases as it is given in the specifications referred to, then we must add a generous amount to our already high estimate. However such a proportion is so far above the average that it is not to be considered. If we are to reduce the high cost of carburizing it is apparent from our consideration of the subject that we must begin by reducing these fixed charges for primary heating and in some way eliminate or at least greatly reduce the cost of pots and boxes.

The solution of the problem does not lie in the improvement or discovery of alloys that will give longer life to the containers but the development of methods that will entirely eliminate them and bring the work into more intimate contact with the source of heat. Such methods will not only result in more economical production but will make possible a higher quality of work than can be produced by the pot method. Already automatic furnaces are operating along these lines in a limited field and the field can easily be broadened by the application of some scientific study of the mechanics of the process. We must also get away from present methods, for the elimination of the danger of the human element: we can not get entirely away from it but we can so reduce it that it can not be the menace it is at present. Automatic furnaces, automatic temperature control and automatic quenching sys-

(*Concluded on page* 1236)

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 41. *Is the X-ray examination of steels commercially practicable?*

QUESTION 42. *Why should high speed steel be delivered only in the annealed condition?*

QUESTION 43. *What is the role of Chromium and Vanadium in steel?*

QUESTION 44. *Is it advantageous for the purchaser to conduct a test on various brands of high speed steel before deciding upon placing his contract?*

QUESTION 45. *What is the value of testing finished tools with a file?*

OLD QUESTIONS AND ANSWERS

QUESTION NO. 8. *What is the effect of high and low silicon in tool steel?*

ANSWER. The greater the percentage of silicon that a tool steel contains, the greater will be the brittleness of the steel. If the content of silicon exceeds one or two per cent the steel will be brittle, in the case of the higher carbon steels, even though the steel be unhardened.

The presence of silicon to the extent of 0.20 per cent, in tool steel or in fact in any steel, which does not contain the nonferrous elements which prevent the formation of graphite, greatly promotes the formation of black steel, that is, steel containing all or nearly all of its carbon in the graphitic form. For example, a steel containing 1.15 per cent carbon or more with a silicon content of 0.20 per cent, is peculiarly liable to black fracture when held for a number of hours at 1300 degrees Fahr.

For the keenest edged tools that possess the most strength and toughness when in the hardened state, there is strong evidence that the lower the silicon content the better, other things being equal. The presence of silicon in crucible steel is unavoidable as under the most perfect reducing conditions of crucible melting, a little of the carbon (graphite) plus silica from the wall of the crucible is reduced to silicon carbide which is absorbed by the molten

steel thereby adding silicon as well as carbon to the steel. Hence tool steels produced under the most perfect reducing conditions of the crucible melting process, having the lowest silicon content commercially practicable, are the highest quality steels for the keenest cutting edges.

As in the case of all steels, the increase of the silicon content renders tool steel more resistant to oxidation at high temperatures and to the attack of acids.

QUESTION NO. 23. Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree

ANSWER. By E. W. Ehn, metallurgist Timken Roller Bearing Co., Canton, O.

At the plant with which the present writer is connected extensive experiments were made some years ago with plain carbon steel in order to determine whether mechanical work on the steel previous to the carburizing operation had any influence on the results obtained in the hardening, and it was found that no such difference was obtained whether the steel was hot rolled, cold drawn or forged. The statement that the hardening was made in oil indicates that the experience referred to in Question No. 23 was obtained with an alloy steel, but there is no reason to believe that a variation in the hardening properties in carburized work will be caused even in this steel by a forging operation previous to the carburizing.

That different steels of similar chemical composition after carburizing respond in a different way to a hardening operation is, however, true and this subject has been dealt with at considerable length in several recently published papers. If different results are obtained in hardening of carburized steel of similar analysis, it is fairly certain, provided that the carburizing and hardening conditions are identical, that this is due to the steel itself and the best method of checking this point is a microscopical examination of the carburized specimens before hardening. A fine grained steel with curly cementite in the hypereutectoid zone indicates a poorly deoxidized steel that will give trouble in hardening, whereas, a good steel will show a hyper eutectoid zone with large solid areas of pearlite and clean-cut cementite lines along the grain boundaries. For details on this subject see answer to Question No. 24 in TRANSACTIONS of American Society for Steel Treating, July, 1922.

QUESTION NO. 26. Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?

ANSWER. By H. A. Schwartz, Manager of Research National Malleable Castings Co. A categorical answer to this question is impossible since quantitative impact tests on identical material differing only with respect to pearlite in the edge are not available. The experimental difficulties of preparing such comparative materials in a form suitable for impact testing appear to be very great.

It is reasonably well established that a white rim increases the tensile strength and decreases the elongation under static loads. Whether the net

result is an increase or a decrease in energy of rupture is not established.

Casual observation in inspecting castings by breaking off test lugs would lead to the conclusion that in extreme cases, at least, the presence of pearlite decreases shock resistance. Only direct experiment, however, would permit one to speak with confidence on the point.

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 30 How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?

QUESTION NO. 35. What is the difference between red annealed and blue annealed sheet steel?

QUESTION NO. 37. What is the role of vanadium in steel?

ANSWER. From a paper by G. L. Norris, presented before the Twentieth Annual Meeting of the American Society for Testing Materials. The metallic element vanadium is one of the fifth group of chemical elements which includes phosphorus, arsenic, antimony, nitrogen, etc. It has an atomic weight of 51.06; specific gravity of 5.5, and melts at 1680 degrees Cent. It is grayish-white in color, non-magnetic, has high electric resistivity, is the hardest of the metallic elements, and the most difficult to reduce. It has not been produced in the pure metallic state. Although discovered in 1830 and soon found to be widely distributed, its known occurrences were in such small quantities that for many years vanadium was considered one of the rarest elements.

The first metallurgical application of vanadium appears to have been in 1896, when it was used in making several heats of steel at Firminy, France. The results of this test showed a remarkable superiority of the vanadium steel in physical properties. Under the same heat treatment, the vanadium steel showed an increase of 44.8 per cent in elastic limit and 31.5 per cent in tensile strength, with slightly lower percentage of elongation but greater reductions of area.

The following discussion will be confined almost entirely to the consideration of pearlitic-vanadium-ternary steel, or simple carbon-vanadium steel, and will not more than briefly touch on the quaternary-vanadium steels. First, however, the writer wishes to touch briefly upon a still somewhat

prevalent popular idea that vanadium is a powerful scavenger, and that the beneficial effects of its use in steel are principally due to its removal of minute, residual amounts of oxygen and nitrogen from the steel. It has even been advanced by some individuals that when all the vanadium added has been completedly used up in scavenging, and none remains in the steel, all the improvement or beneficial effects possible have been accomplished; despite the fact that there is an increase in the mechanical proprties of the steel with increasing amounts of vanadium present, and that vanadium has equally as great beneficial effects in steels made under reducing conditions such as crucible and electric furnace steels, as in the case of steels made under oxidizing conditions like open-hearth and Bessemer steels. While it is true that vanadium oxidizes readily and will combine with nitrogen, its value as a scavenger is negligible, as there are much cheaper metals that are as effective, or perhaps more so.

The remarkable effects of vanadium on steel are due entirely to its presence in the steel as an alloying element, and its influence on the other constituents with which it is in combination. When added to steel it is found in both the main constitutents, ferrite and pearlite, but principally in the latter. Only a few hundredths of one per cent of the vanadium combines with the ferrite. This minute amount, however, appears to increase the strength, toughness, hardness and resistance to abrasion of the ferrite. Nearly all the vanadium, however, is found in the pearlite, in chemical combinations with the cementite, as a compound carbide of vanadium and iron in the case of ternary steel, and as more complex carbides in the case of quaternary steels.

Vanadium replaces the iron in the cementite or the carbide by increasing amounts until finally when the percentage of vanadium is about 5 per cent all the iron has been replaced by the vanadium. The vanadium-containing cementite is not as mobile as ordinary cementite and consequently does not segregate into as large masses, but occurs in relatively minute particles and, therefore, is more uniformly distributed. It does not, consequently, readily occur as lamilar or thin plates in the pearlite, but in a granular or sorbitic condition. This strong tendency of vanadium to form sorbitic and even troostitic pearlite, is doubtless one of the reasons for the mechanical superiority of steels containing vanadium, not only statically but dynamically.

Vanadium carbide is not as readily soluble on heating as iron carbide, and consequently vanadium steel requires a higher temperature to dissolve the cementite and put the steel in the austenitic condition for quenching.

The presence of vanadium does not raise the Ac1 and Ar1 points more than about 10 degrees Cent., and repeated heatings do not seem to lower the Ar1 point. The Ac2-3 and Ar2-3 points are raised somewhat more and continue to rise with increase in percentage of vanadium.

The effect of vanadium on the physical or mechanical properties of steel increases with the percentage of vanadium until about 1 per cent is present, after which there is a decrease, even in the case of quenched steels, and with 3 per cent or more of vanadium the steel is actually softened on quenching until unusually high temperatures are reached, say about 1300 to 1400 degrees Cent.

Vanadium steel hardenite has a greater thermal stability, or power to withstand elevated temperatures without softening or breaking down or separation of cementite. This property is responsible for the great improve-

ment in high-speed steels, through the addition of vanadium to stand up longer under the high temperatures developed at the point of the tool in taking heavy cuts at high speed. Percentages of vanadium as high as 3.50 have been successfully used in high-speed steel, and 1.50 to 2.50 per cent are not uncommon, although only a few years ago the percentage ranged from 0.30 to 0.75, and it was thought that the addition of over 1 per cent gave very little additional advantage. The improvement in high-speed steel through the use of vanadium has borne an almost direct relation to the percentage of vanadium present, and is considered to be from 60 to 100 per cent.

In the case of carbon-vanadium tool steel the use of vanadium has proved almost equally beneficial, although at present only about 0.2 per cent of vanadium is used in such steel. It has a wider quenching range—that is, can be heated higher without injury,—hardens deeper, retains cutting edge longer, and is very much tougher and stronger. A bar of 1-per-cent carbon tool steel containing 0.25 per cent vanadium, quenched and drawn back at 400 degrees Cent., will bend 90 degrees without failure whereas a similar steel without vanadium will bend only about 20 or possibly 30 degrees. Comparative compression tests of such tool steels with like tempering or draw back gave on 1¼ inch cubes, 490,000 pounds for the vanadium steel and 278,000 pounds for the steel without vanadium. For battering tools, such as pneumatic chisels, sets, calking tools, rock drills, etc., vanadium tool steel possesses marked superiority on account of its combination of hardness, strength and toughness.

One of the principal applications of vanadium steel has been for steel castings, particularly for locomotive frames. The composition of the steel is the same as usual for such castings, excepting for 0.15 per cent or more vanadium. The addition of this small amount of vanadium increases the elastic limit of the annealed castings 25 to 30 per cent without lowering the ductility. The tensile strength is not increased proportionately in the case of thoroughly annealed castings, but is usually 10 to 15 per cent greater.

There is also doubtless a great future for vanadium-quaternary steel castings, both annealed and heat-treated—particularly the latter—for, as in the case of forged or rolled quaternary steels, the improvement in the mechanical properties from the presence of vanadium would be much greater even than in the case of simple carbon-vanadium steel. The value of vanadium in simple carbon forging steels has been over-shadowed by the greater mechanical properties of the vanadium-quaternary steels, such as chrome-vanadium, yet they have mechanical properties equal to those of ordinary 3-per-cent nickel steel under like conditions. Excepting where the very high physical properties obtainable from quaternary steels are desired, carbon-vanadium steel can be used to advantage, especially for large forgings.

This steel presents fewer manufacturing difficulties than quaternary steels. It is less liable to losses from shrinkage cracks and checks in the ingot, and to heating and cooling strains in the forging and heat-treatment operations. It requires no more special care in handling than ordinary carbon steel, and is worked with equal facility.

Carbon-vanadium forging steel in the normalized condition, which may be described as annealed for grain refinement, has physical properties superior to those specified for heat-treated carbon-steel forgings. This simple treatment alone, therefore, gives physical properties sufficiently high for a great number of forgings that would otherwise have to be quenched and tempered.

A large field for annealed or normalized carbon-vanadium steel is its

use for locomotive forgings. It is generally conceded that there is need of a steel of greater strength, not only to meet present conditions, but also to permit of reducing sections of reciprocating parts to obtain better counterbalancing. To meet this requirement, the railroads several years ago turned to heat treated carbon and heat-treated alloy steels, notably chrome-vanadium. The use of heat-treated locomotive forgings has not proved altogether satisfactory for a number of reasons. One objection to the use of these forgings is the lack of heat-treating equipment in most of the railroad shops. This operates particularly in repair work where for any reason the forging has to be locally heated to straighten, stretch or shorten, destroying thereby the effect of the original heat treatment and producing inequalities which may result in failure. Probably no other class of forgings is subject to as abusive use as locomotive forgings, and under such conditions ordinary heat-treated forgings have not been found reliable. For these and other reasons annealed forgings are preferred. Consequently, as steel that could give in an annealed condition physical properties equal to or even better than those specified for heat-treated carbon-steel forgings, would prove very desirable.

Nickel-Vanadium steel, while having possibly even higher tensile properties than chrome-vanadium steel, is considerably more expensive and has not been found to meet all conditions as satisfactorily as chrome-vanadium steel. It does not appear to have as high a resistance to shocks and repeated stresses.

QUESTION NO. 38. What regulations are recommended to reduce the fire hazzard of quenching tanks?

QUESTION NO. 39. What happens to a piece of steel when it is tempered or drawn back after quenching from above the upper critical point?

ANSWER. By Walter M. Mitchell, Philadelphia, Pa. Above the upper critical point, which is the limit of the critical range, iron and carbon mutually dissolve forming a solid solution which is stable only at temperatures above this range. If this solid solution is cooled slowly through the critical range it will decompose with the separation of the iron and carbon, (the latter in the form of cementite), which decomposition requires a definite length of time for its completion. If, however, the solid solution is cooled suddently, as by quenching, sufficient time for decomposition will be denied, and the steel will be retained, "frozen" as it were, in the condition of solid solution. This is an unstable condition when existent at ordinary temperatures, and thus we have the steel in a condition which is stable at one temperature, existing at some other temperature at which it is not stable. Such a condition will tend to become stable if the proper agent is provided which will overcome the rigidity of the cold metal. This agent is heat; and its effects in the operation of tempering is to produce plasticity or "loosening" which will permit relief from strain and atomic adjustment; the metal approaching more and more as the temperature, or the time held, is increased, the normal condition; i. e., that which is stable at ordinary temperatures.

As a comparison we may imagine a rubber band, which has been stretched and by some means frozen in the stretched condition—this represents the

quenched steel. If a slight heat is applied so as to "thaw" the rubber it will gradually return to its normal condition; the higher the temperature the more quickly will this take place.

Now as regards the effect of tempering on physical properties. In the quenched condition steel consists largely of the constituent martensite. Martensite is very hard, space will not admit of the discussion why this is so, other than to say that its hardness is due possibly to two causes: the greater attraction between unlike atoms (iron and carbon) resulting from the hetrogeneous atomic mixture in the solid solution, which is simply a particular case of the general rule that metals are hardened and strengthened by the addition of elements which dissolve in them to form solid solutions; and the extreme fineness of grain structure developed during the quenching operation. Now if the solid solution is decomposed in the tempering operation the result will be a coarsened grain structure and increased separation of the iron and cementite particles, which will be accompanied by increased softness and ductility. With the progress of the tempering operation there will be formed a series of transformation products which are individually characteristic and identifiable under the microscope, and possess definite physical properties. These products have been named troostite, sorbite, and pearlite, and represent advancing stages in the separation of iron and cementite; each one being a decomposition product of the former, and hence softer and more ductile than it. Thus the object of the tempering operation is to allow the decomposition of the solid solution to proceed to the proper degree, and thus produce that constituent in the steel which will have the desired physical properties.

ANSWER. By H. J. French, Physicist, U. S. Bureau of Standards. The effects observed in tempering hardened steel will depend upon its composition, size and shape, details of the method of hardening, etc. Therefore the very general nature of the question precludes an adequate reply in the limited space available except by referring the inquirer to well recognized books and reports related to the heat treatment of steels in which very complete discussions will be found.

It may however, be helpful to consider briefly from a theoretical standpoint, some of the principal effects of tempering carbon steel, of such composition, size and shape and quenched in such a manner from above the upper critical range, that it has been "completely hardened throughout." Because such steel shows a structure called martensite when examined under the microscope it is called martensitic or completely hardened steel by the metallographist. The rapid cooling required to produce this condition has left the metal in a highly stressed condition and while there is a tendency for readjustment and relief of these stresses such changes proceed slowly, at least after a brief space of time, because of the regidity of the hard-
at least after a brief space of time, because of the rigidity of the hardened steel.

When heat is applied, for example at 100 degrees Cent. (212 degrees Fahr.) the metal becomes more plastic and somewhat more advanced readjustment is possible so that the first effect observed is a change in dimensions of the hardened steel. As the temperature is further increased the dimensional changes continue. When the steel is tempered at about 250 degrees Cent., a decrease in hardness and a partial change in structure of the martensite to that called troostite are observed. With increase in tem-

pering temperatures to just under the transformation range, the steel becomes progressively softer, more ductile, and continues to change in dimensions; the full martensitic structure gradually disappears until the steel becomes troostitic, and then sorbitic, as is shown in Fig. 1. Accompanying these structural changes are a decrease in strength and elastic limit. Likewise changes in other properties such as electrical conductivity, density, magnetic properties, etc., occur but the limited space available does not permit

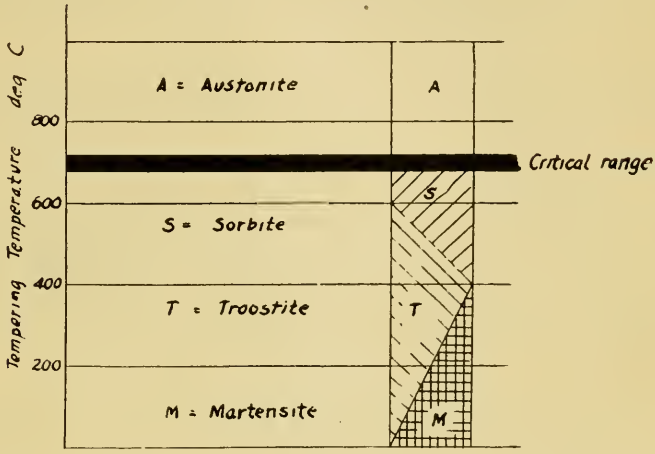

Fig. 1—Diagram depicting the tempering of hardened steel originally all martensitic. (After Sauveur).
Note: The distance—horizontally—within the block for any tempering temperature represents proportions of martensite, troostite, etc., theoretically present.

more detailed consideration of these effects. The important feature is that in hardening the steel the transformation which normally occur in slow cooling are largely prevented from taking place and the metal is considered to be in an unstable condition. Tempering permits the arrested transformations to advance more and more to completion as the temperature is increased.

If austenite is retained in quenching, (a condition which may readily be obtained in many of the alloy steels), changes upon tempering are complicated. When troostite is first formed one less stage in the advancement of the transformations to completion is observed.

Detailed discussion of the hardening and tempering of steels may be obtained from the following texts:

Steel and Its Heat Treatment. D. K. Bullens, Pub. John Wiley & Sons, New York, N. Y.

Metallography and Heat Treatment of Steel. A. Sauveur, Pub. Sauveur & Boylston, Cambridge, Mass.

Steel: Its Selection, Annealing, Hardening and Tempering. E. R. Markham, N. W. Henley Pub. Co., New York, N. Y.

QUESTION NO. 40. *What is the influence of a low percentage copper content in steel?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

RESISTANCE TO CORROSION OF VARIOUS TYPES OF CHRONIUM STEELS. By Henry S. Rawdon and Alexander I. Krynitsky, Physicist and associate physicist, Bureau of Standards. *Chemical and Meatllurgical Engineering*, Vol. 27, No. 4.

Several pure Chromium steels, in the cast, forged and heat treated conditions were observed during immersion in dilute hydrochloric acid and in aerated distilled water. Two types of tests were used, one for determining the resistance of the materials to corrosive attack by acid and the second being a simulated "weather" test. Tables show the effect of the various heat treatments upon their resistance to corrosion attack. The effect of the various elements present in the steels are discussed.

NOTES ON ACID ELECTRIC FURNACE PRACTICE. By C. W. Francis, *Iron Age*, Vol. 110, No. 6, pages 345-346.

A discussion of the steel foundry melting practice in the U. S. and the use of basic steel scrap in acid furnaces.

SCIENTIFIC SELECTION OF MATERIALS FOR FORGINGS. Special Correspondence, *American Machinist*, Vol. 57, No. 6, August, 1922, Pages 211-215.

A paper covering the selection of steel to suit the job including a discussion of the various testing machines and equipment used in determining the quality of the material. The importance of proper heat-treatment as supervised by the metallurgical laboratory.

STAINLESS STEEL AT HIGH TEMPERATURES. By H. J. French, *Iron Age*, Vol. 110, No 7, August, Pages 404-405.

Stainless steel of 0.30 per cent carbon and 13 per cent chromium has been successfully used for valves operating at high temperatures. Curves are presented showing the physical properties of this type of steel under various temperatures. Photographs of fractures of this steel broken in tension are exhibited.

MALLEABLE CAST IRON. By Enrique Touceda. *American Machinist*, Vol. 57, No. 9, pages 321-325 August, 1922.

A discussion of the qualities of pure cast iron and steel as compared with the same qualities of malleable castings. A few photomicrographs of these metals are shown. A brief discussion of the melting, pouring and annealing of malleable cast iron together with its characteristics as finished for use.

THE DECOMPOSITION OF MARTENSITE INTO TROOSTITE IN STEELS. By Howard Scott of U. S. Bureau of Standard. *Forging and Heat Treating*, July, 1922, pages 296-299.

The effect of the alloying elements, manganese, silicon, nickel, cobalt, tungsten, chromium, vanadium and molybdenum, on the decomposition of martensite to troostite was determined by means of heating curves. Only three of these elements showed a marked effect, namely, manganese, silicon and chromium. The first named increased the intensity of the transformation, while the last two raised its temperature when present in in certain percentages. None of the alloying elements lowered the transformation and no general relation was found to exist between it and the higher critical point Ac_1. The significance of these data in regard to heat treatment and properties of alloy steel is discussed.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

NEW FORMULA DERIVED

A recent communication from F. H. Baldwin of Bethlehem, Pa., contained the following comments in reference to the physical properties of S. A. E. steel No. 1045. Mr. Baldwin says:

"In reviewing the tabulation of the ultimate tensile strengths of steels, published by the Society of Automotive Engineers, it occurred to the writer that the relationship between the different values was governed by a circular function, and as a result he has become so interested in this matter that he has worked out this idea. Believing that readers of TRANSACTIONS might also wish to have this information, he is transmitting the formula covering S. A. E. steel No. 1045 in the hope that it may stimulate a discussion.

$$T = 110 + 15\tfrac{1}{2} \operatorname{Sin} (9\text{-}t)\ 15^{\circ}$$

where T = Ultimate tensile strength / 1000

t = Drawing temperature degrees Fahr. / 100

Applying the formula to the tabulation, the following comparative results are obtained:

Drawing Temp. Degrees Fahr.	Ultimate Strength Pounds Pounds Per Square Inch Formula	Pounds Per Square Inch S. A. E.
400	125,000	125,000
500	123,400	123,500
600	120,950	121,000
700	117,750	118,000
800	114,050	114,000
900	110,000	110,000
1000	105,950	106,000
1100	102,250	102,000
1200	99,050	99,000
1300	96,600	96,500
1400	95,000	95,000

In presenting these figures the writer wishes it to be understood that he is simply offering an explanation of the relationship obtaining between the published values as given by the Society of Automotive Engineers."

PAPER CORRECTED

Attention has been called to the fact that an error existed in G. C. McCormick's paper entitled "Furnace Atmospheres and Their Relation to the Formation of Scale" published in August TRANSACTIONS, on page 1012. The second line should read "carbon monoxide present," and the sentence preceding the paragraph 'Conclusions,' should read:

> "It, therefore, appears logical to conclude that regardless of the presence of carbon monoxide in the furnace atmosphere, scaling will take place when the temperature is sufficiently high and the time of heating is sufficiently long."

Reviews of Recent Patents

1,410,566. Electric Furnace. William S. Hadaway, Jr., of New Rochelle, N. Y.

This invention relates to improvements in electric furnaces and especially to a new type of apparatus for obtaining high temperatures at low cost. One object of the invention is to provide a simple apparatus for supporting combustion wherein the temperature of admitted vapor is raised above the ignition pont of the fuel by electrical energy. Another object is to provide an automatic means for controlling the electrical energy for the heaters. A still further object is to provide means for admitting air to the combustion chamber where it may be combined with the flame and increase the efficiency of the apparatus.

1,414,366. Method of and apparatus for heat treating metallic articles. Harry P. Macdonald, Montclair, N. J., assignor to Snead & Company.

Method of heat treating metallic articles which consists in cutting off the heat and in quenching at approximately the end of the critical period.

1,414,489. Annealing and other furnace. Ralph C. Stiefel, Ellwood City, Pa.

In combination with a heating furnace provided with openings in opposite ends thereof, of a table immediately adjacent each end of the furnace on a level with the bottom thereof, a pair of connected work carriers movable on said tables and on the furnace bottom, and mechanism for drawing said work carriers simultaneously and alternately in opposite directions, said work carriers being spaced apart, and each having a total length less than the length of the furnace whereby when either thereof is in the furnace the other one is entirely outside the furnace on one of the tables for loading and unloading.

1,415,261. Process of case hardening articles. George C. Nixon and Frederick Charles Raab, Syracuse, N. Y.

The process of carburizing metal, which process includes covering the portion of the article to be carburized with adhering carbonaceous material under pressure sufficient to cause the same to rigidly adhere to the article and form a relatively thick layer thereon, and then heating the article with the carburizing material thus secured thereon.

1,416,006. Supporting apparatus for use in tempering furnaces. George M. Eaton, Pittsburgh, Pa., assignor to Westinghouse Electric & Manufacturing Company.

A supporting apparatus for use in tempering furnaces comprising a base and three spaced supporting means carried thereby.

1,416,221. Connection for liquid-fuel burners. Gustave C. Lorenz, Milwaukee, Wis., assignor to A. J. Lindemann & Hoverson Company, Milwaukee, Wis.

A connection between the liquid fuel supply pipe and the burner of a liquid hydrocarbon stove comprising a member secured to the supply pipe and having an upwardly extending tabular portion, a tabular member connected with and extending downwardly from the burner, and telescoping with the said upwardly extending portion, an annulus of relatively soft material on one of said members, said annulus having beveled surfaces and adapted to act as a seal for the joint of the said telescoping members, one of the said members also having a beveled

portion in contact with the said annulus, the respective angles of the two beveled portions being different in degree.

1,414,614. Muffle furnace. Johannes Robert Carl August, Halifax, England. A rotary furnace of the rotary barrel type, formed by the combination of a rotary heating chamber closed at one end, and having a central aperture at the other, and a removable muffle or barrel inserted closed end first through the said aperture while the open end which is closed by a detachable cover is left projecting, the space between the rotary heating chamber and the barrel being subdivided by longitudinal bearers into a plurality of longitudinal flues for the hot gases to pass through, the bearers forming throughout their lengths supports for the muffle which rotates with the heating chamber.

1,422,572. Mold for hot-top ingots. S. E. Hitt of Elyria, Ohio, and J. I. Peyton of Chicago, Ill., propose an ingot mold whose topmost part is hollow cast.

A vacuum is maintained in this space and it is claimed that by this means the top part of the solidifying ingot will remain liquid much longer than the lower, thus acting as a sink-head to fill any pipe or contraction cavity which may be formed. A hollow-cast top may also be bolted to the top of an ordinary mold. Various precautions are mentioned concerning the manufacture of the mold, its design and the maintenance of the proper vacuum.

BRITISH PATENTS

178,107. Microscope condensers. C. Zeiss, Carl-Zeiss-Strasse, Jena, Germany. April 3, 1922 No. 9471. Convention date April 6, 1921. Class 97 (i).

The text of this patent refers to illustrations for purpose of description. A dark-ground immersion condenser for microscopes are constructed of two members *c*, *c*, of which the member *c* nearer to the source of the light is adjustable axially in relation to the other member *c* so that object slides of differing thickness may be used. The upper suface c^2 of the lower member is concentric with that of the lower surface of the lens *c*, being separated from it by an air gap. Light entering from below is reflected from the parabolic surface e^1 to the lens *c*, passing across the air gap substantially normal to the adjacent surfaces. Adjustment is effected by rotation of the lever *f* secured to the screwed mount *d* of the member *c*.

178,722. Furnaces. South Metropolitan Gas Co. and Chandler, D., 709, Old Kent Road, London. April 22, 1921, No. 11699 [Classes 51 (i) and 51 (ii).]

A gas-fired metallurgical furnace comprises a sloping floor 1 leading to a solid well-hearth 2, burners 4 being provided in the roof 3 and arranged at a tangent to the rear portion of the hearth. The products of combustion, after passing over the hearth, return in the opposite direction over the sloping floor to side flues 5, through which they pass to flues 6 arranged beneath the floor 1 so that the charge is preheated before it reaches the hearth. A skimming-door 9, having an inspection window 10, is provided at the front of the furnace and the hearth 2 is formed with a discharge spout 11 the passage to which is closed by a loose brick 12.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ALLEE, H. DONALD, (M-9), 58 Delaware Ave., Detroit, Mich.
ANDERSON, O. L., (M-7), 3649 Canfield E., Detroit, Mich.
ANDERSON, GEO. A., (M-8), 1149 Hudson Ave., Detroit, Mich.
BEAUDRY, ROLAND, (M-8), 685½ Mineral St., Milwaukee, Wis.
BROWN, F. G., (M-8), Trumbull Steel Co., Warren, Ohio.
BURKET, H. D., (M-9), Bourne Fuller Co., Upson Works, Cleveland, Ohio.
CHAMBERS, A. A., (M-5), 225 32nd St., Milwaukee, Wis.
CHANEY, CARYL, E., (M-9), 97 Pilgrim Ave., H. O., Detroit, Mich.
COBLE, C. C., (M-5), 1540 Charles St., Rockford Ill.
CRAMER, HOWARD S., (M-8), 1421 S. Los Angeles St., Los Angeles, Cal.
EBERHARDY, W. W., (M-8), 377 Beulah Ave., Milwaukee, Wis.
FOLTZ, ROSS M., (M-5), 587 14th Ave., Wauwatosa, Wis.
FOREMAN, CHAS. L., (M-8), 1605 Stone St., Flint, Mich.
GRIES, GEO. G., (A-8), 1054 Book Bldg., Detroit, Mich.
HARTDEGEN, H. O., (A-8), 943 Book Bldg., Detroit, Mich.
HELLENBERG, CARL E., (A-5), 231 California Ave., Detroit, Mich.
HARRIS, F. E., (M-8), 205 W. Anne St., Flint, Mich.
HENNING, PAUL H., (M-5), c/o Detroit Screw Works, Detroit, Mich.
HERGENROETHER, E. J., (M-8), Cadillac Motor Car Co., Clark Plant, Detroit, Mich.
ILLINGWORTH, C., (S-7), Tacony & Lewis Sts., Frankford, Philadelphia.
JARBOL, JAMES, (M-8), 2540 Lycaste St., Detroit, Mich.
KENDALL, F. G., (A-8), Rosedale & Ocean Aves., Rosedale June., N. Y.
LEWIS, C. B., (M-8), 139 Canfield Ave., West, Detroit, Mich.
LUTZ, WM. O., (M-2), 2093 E. 40th St., Cleveland, Ohio.
MALLOY, THOS. F., (M-8), Crucible Steel Company of America, 540-541 Tokyo Kaijo Bldg., Marunouchi, Tokyo, Japan.
McLURE, NORMAN R., (M-7), Bullitt Bldg., Philadelphia, Pa.
MILLETT, KENNETH B., (M-9), 90 West St., New York City.
MOORE, W. J., (A-8), Ford Bldg., Detroit, Mich.
MUELLER, F., (M-9), Standard Chemical Co., Canonsburg, Pa.
NIXON, H. K., (M-8), 326 Hendrie St., Detroit, Mich.
NOONAN, R. F., (A-5), 7765 So. Shore Dr., Chicago, Ill.
NELSON, EDWARD N., (A-8), 1222-425 E Water St., Milwaukee, Wis.
PAGE STEEL & FLAGG CO., (S-7), 111 Court St., New Haven, Conn.
PERRY, E. B., (M-8), c/o Industrial Works, Bay City, Mich.
PLOTNER, W. F., (M-4), 1009 Monroeville Rd., Turtle Creek, Pa.
RAMSEY, JOS. H., (M-7), c/o Albany Mach. & Tool Co., Albany, N. Y.
REED, EVERETT, (M-9), 19 Westmoreland Ave., Arlington Hts., Mass.
SCHAFER, OTTO H., (M-8), 9112 Witt St., Detroit, Mich.
STONE, HARRY, (A-8), Automotive Prod. Corp., Hazelton, Pa.
THURNER, WM. J., (M-5), 1203 Sycamore St., Milwaukee, Wis.
TUNG, T. S., (Jr-5), 353 Atwood St, Oakland Sta., Pittsburgh, Pa.
WAGAR, T. E., (M-8), 956 Melbourne Ave, Detroit, Mich.
WHITE, E. C., (A-8), 403 Real Estate Ex. Bldg., Detroit, Mich.
WIGGINS, C. R., (M-8), 434 Thompson St., Flint, Mich.
WILLIAMSON, WM., (M-8), 467 Bewlah Blvd., Milwaukee, Wis.

MAIL RETURNED

EHRMANN, CHAS. H. T., of Eastman Kodak Co., State St., Camera Works, Rochester, N. Y.
GEHLERT, WM. E., (M-4), 630 Washington St., Gary Ind.
MOULDER, (M-5), 1419 Porter St., Philadelphia, Pa.

CHANGES OF ADDRESS

ANDERSON, F. E., (A-5), from 117 Mitchell St., to 553 Fruit Hill Ave., Providence, R. I.
BATE, H. A., (M-4), from 36 Grant St., Munhall, Pa. to 428 Victoria Ave., Lackawanna, Pa.
FISCHER, G. H., (M-10), from 202 Maple St., Massillon, Ohio to Interstate Iron & Steel Co., 118th St., Plant So. Chicago, Ill.
GUISWITE, R. D., from 418 15th Apt. 42 to 1201 Park Ave., Indianapolis, Ind.
HUNNINGS, S. V., from Washington Steel & Ordnance Co., to 2826 27th St., Washington, D. C.
JAYME, WALTER A., (M-8), from 3716 Brighton Rd., Pittsburgh, Pa. to 1120 Piedmont Ave., N. E., Canton, Ohio.
JOHNSTON, R. L., (M-3), from Aluminum Die Casting Co., 87 35th St., Brooklyn, N. Y. to Garwood, N. J.
KENNEDY, WM. M., (M-10), from Park Steel Works, 30th & Smallman Sts., Pittsburgh, Pa. to N. Bloomfield, Ohio.
KURRASH, C. A., (M-9), from 717 Cedar St., Michigan City, Ind. to 9828 Winston Ave., Chicago, Ill.
LAWRENCE, GEO. L., (A-10), from 7709 S. Morgan St., Chicago, Ill. to 134 S. LaSalle St., Aurora, Ill.
LOEBELL, H. O., from 60 Wall St., to 24 State St., New York City.
MARTELL, FRED, (M-5), from 905 S. Lafayette St., to 1526 So. Main St., South Bend, Ind.
McGAHEY, W. E., (M-12), from 12 White Ave., S. Charleston, W. Va. to 105 Highland Ave., Covington, Va.
MEYERS, A. L., from Lukens Steel Co., Coatesville, Pa. to Ivy Rock plant Alan Wood Iron & Steel Co., Conshohocken, Pa.
OLIVER, W. O., (M-5), from 308 Kennedy Rd. to Steel Co. of Canada Ltd., Toronto, Ont., Canada.
RICHARDSON, A. A., (M-4), from 274 Farmington Ave., to 11 Barnard St., Hartford, Conn.
TISSING, D., (M-12), from 1058 N. Chatsworth St., to 1032 Argyle, St. Paul, Minn.
TREADWAY, ALFRED A., (A-2), from 710 Glynn Court, to 7644 Woodward Ave., Detroit, Mich.
WAISNER, H. L., from 218 So. Second St., to 1126 Grant Ave., Rockford, Ill.
WARD, A. C, (M-5), from Rolls Royce Co. of America, to 546 Page Blvd., E. Springfield, Mass.
WILEY, C. D., (M-5), from 1220 N. Dearborn St., to 4144 Claredon Ave., Edgewater Sta., Chicago, Ill.
WILKIE, J. C., from Western Automatic Machine Screw Co., Elyria, Ohio to 5165 Second Blvd., Detroit, Mich.
WOLF, ERNEST, (Jr-6), from 3377 W. Congress St., Chicago, Ill. to Lewis Institute, Chicago, Ill.
ZORNIG, COL. H. H., from Watertown Arsenal to 305 Mt. Auburn St., Watertown, Mass.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

SALES REPRESENTATIVE—At present holding responsible executive position. Desires to become representative of one or more manufacturing lines in excellent territory. Companies especially desiring representative for materials used in heat treating will find it to their advantage to correspond with No. 7-5.

CHEMIST AND METALLURGIST—thoroughly experienced in analysis of ferrous and nonferrous metals. Specialist in alloy steel analysis. Capable of taking charge of chemical and physical laboratory. Best of references. Age 30. Married. Salary commensurate with ability. Answer 7-20.

METALLOGRAPHIST desires position in charge of or as assistant in metallographical laboratory. Has had four years experience U. S. Bureau of Standards. Address 8-10

WANTED by a practical man with 22 years' experience with some leading firms of the United States, position as Supervisor or foreman of Heat Treating. Address 8-5

UNUSUAL opportunity to secure exclusive sales agency for tool steel mill in Detroit and Los Angeles districts. Mill long established and products of proven quality. Would require experience in selling steel and moderate capital. Address 9-15.

STEEL METALLURGIST and SALES MANAGER having had ten years experience in the automobile industry in Cleveland & Detroit desires to make a change in situation. Detroit or vicinity preferred; however, will go elsewhere depending upon the proposition. Salary desired $5000. Address 9-10.

YOUNG MAN with four years experience in the heat treatment of steel and who has taken a course in metallography, wishes a position with some concern where there is a chance for advancement. Best of references. Address 9-1.

POSITIONS OPEN

POSITION OPEN as Assistant Metallurgist with large plant making bearings. College graduate with some years practical experience in heat treating or steel mill work preferred. State in reply education, experience, and salary desired. Address 9-5.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specialized in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-15.

(*Continued from page* 1221)

tems are the means by which costs may be reduced, quality raised and man's fallibility minimized.

Conclusion

The fixed charges of carburizing should and can be reduced to less than 1 cent per pound where there is steady production of standard parts and the total cost should not exceed twice the amount of the fixed or primary costs. This does not apply to carburizing operations in commercial steel-treating plants, of course, where production costs must be reckoned on a great variety of work and will vary from 3 cents per pound to three times that amount. But in cases such as referred to the ultimate cost of carburizing and heat-treating standard parts should not exceed 2 cents per pound if the proper methods and equipment are employed.

Commercial Items of Interest

Sir Robert A. Hadfield, Bart., president of Hadfields, Ltd., has been elected president of the Engineers' club of London, taking office Sept. 1 in succession to E. Manville, M. P., whose term expires,

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The Doehler Die Casting Co., Court and Ninth streets, Brooklyn, N. Y., has arranged for an increase in capital from $1,500,000 to $2,000,000.

The United States Civil Service Commission announces a competitive examination for the position of Associate Physicist qualified as a naval mine technician. Complete information regarding the qualifications for this position may be obtained from the Civil Service Commission at Washington, D. C., or from a civil service officer in any post office or custom office.

Further expansion has been decided on at the Cumberland, Md., plant of the N. & G. Taylor Co., Philadelphia. A larger power house is to be built with improved type of boilers, automatic stokers, coal handling machinery and the like. Additional capacity has been added to the tin house to meet the demand for roofing plate, the company being conspicuously a maker of tin and terne plate. All the open-hearth furnaces of the plant are reported in operation and the bar mill has been running day and night turns.

W. H. White, formerly connected with the United States Naval Ordnance plant, Charleston, W. Va., has been appointed superintendent of the open-hearth department Pittsburgh Crucible Steel Co., Midland, Pa., succeeding L. A. Lambing, resigned.

Thomas A. Wickenden and Charles McKnight, Jr., have recently joined the development and research department of the International Nickel Company, New York City, to undertake development work in connection with alloy steels. Mr. Wickenden was for many years associated with the Studebaker Corporation as Engineer in Charge at their South Bend Plant, and more recently associated with the Zeder-Skelton-Breer Engineering Company in a consulting capacity. Mr. McKnight was formerly Works Manager of the Carbon Steel Company and engaged for many years in the production of alloy steels.

Tate-Jones & Co., Inc., of Pittsburgh, are now building two rotating

hearth electric furnaces for the Continental Motors Corp., Muskegon, Mich., which will be used for the continuous heat treatment of connecting rods for motors. One furnace will be used for the quenching operation and the other for the draw-back.

The furnaces have a rotating hearth 22 inches wide and 7 feet 10 inches in diameter with charging and discharging doors at one side. The furnaces are heavily insulated and the heating element consists of ribbon resistors made by the General Electric Company placed on the side walls, having Leeds & Northrup control.

Celite Products, Limited, has been established in Canada to market Sil-O-Cel and Filter-Cel as produced by the Celite Company in the United States. Sil-O-Cel is widely used for the prevention of excessive heat loss from boilers, furnaces, etc., and is a very high efficiency temperature insulation. It is furnished in brick, block, powder, and cement forms and may be applied to all types of heated equipment without change in design. Filter-Cel is used as an aid in filtering to secure greater clarity and brilliance of filtrate. Its use reduces operating costs by increasing the rate of flow and by enabling the filters to operate in longer cycles. Stocks of these materials will be maintained in Montreal. Mr. Lawrence Russel has been appointed manager with offices in the New Birks Building.

Various grades of one brand of high speed tool steel made by the Firth-Sterling Steel Co., McKeesport, Pa., are described and their specifications given in a comprehensive booklet just issued. The maker calls attention to the many uses to which this steel can be put and points out the six factors to be considered in selecting high speed steels, namely, red hardness, density, minimum distortion, high heat treatment, price, and service and shipment. Each of these factors then is discussed in detail. Some 20 pages of the total of 44 carry a Centigrade-Fahrenheit conversion scale, a classification of standard sizes and extras and price quotations. This company has established the practice of publishing a booklet on each particular brand of steel manufactured in order that the user can find quickly in concise form all the available data about the brand in which he is interested. Three other booklets now are available.

Walter H. Haupt has recently joined the sales force of the Colonial Steel Company, Cincinnati, Ohio.

The Claude S. Gordon Company announces that they are now located at 708 to 714 West Madison street, Chicago. The Gordon Company specializes in heat treating furnaces, pyrometers and accessories including gauges, ther-

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